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ABSTRACT

This activity manual is divided into 15 units which focus on: the nature of science; metric measurements; properties of matter; energy; atomic structure; chemical reactions; acids, bases, and salts; temperature and heat; readioactivity; mechanics; wave motion, sound, and light; static charges and current electricity magnetism and electromagnetism; electronics; and space science. Each unit contains an objective, instructional strategies (which provide background information for concepts fostered), activities, and applications and implementation (in which past, present, and future experiences of students are related to the concepts demonstrated in the activities). Activities may include demonstrations, individual and guided experiences, and laboratory experiences. Each of them explains a concept by the use of visual, tactile, auditory, and kinesthetic teaching/learning styles. Brief comments on safety and the objectives and content for a general physical science course are included. (JN)

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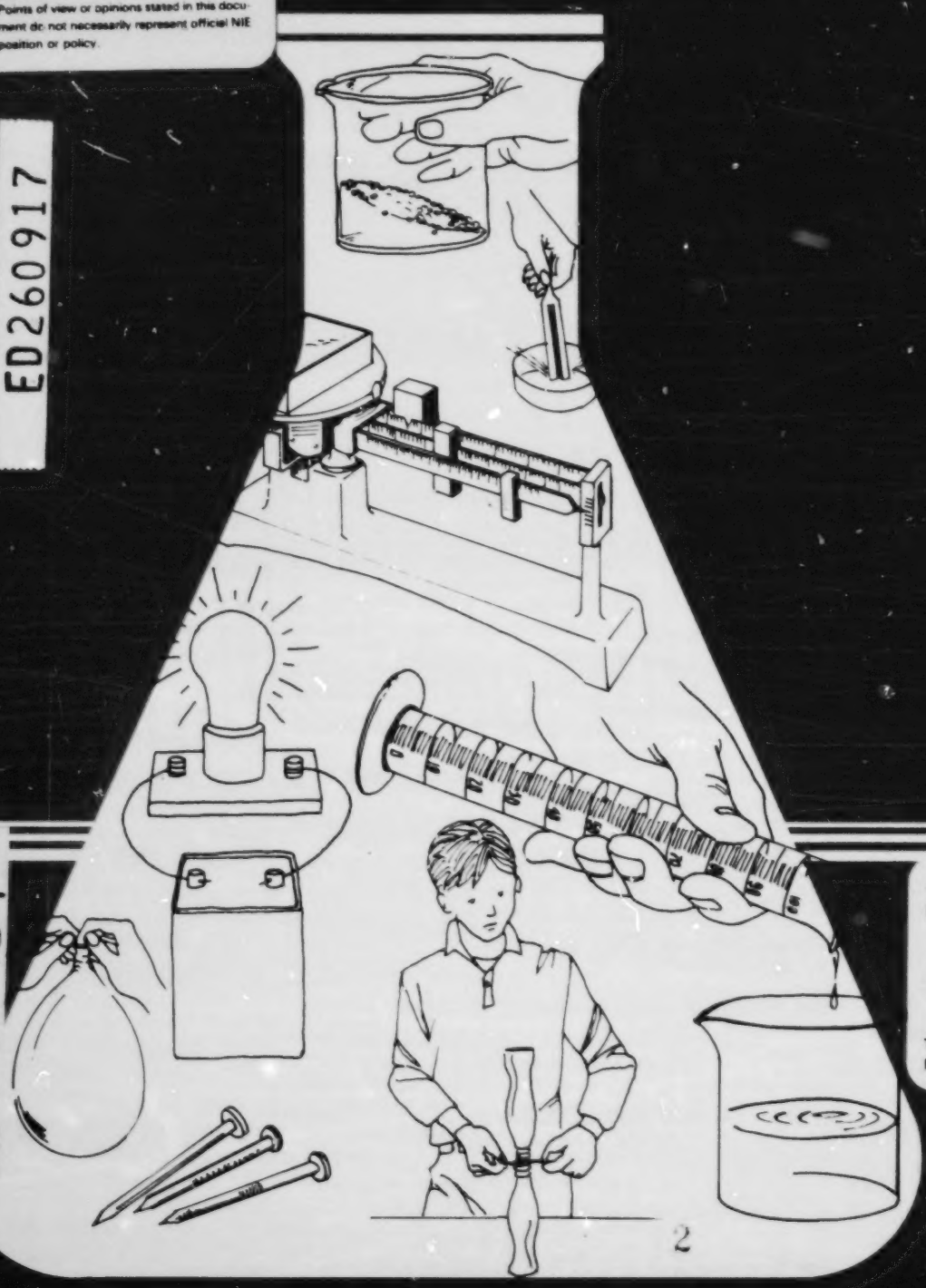

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DEVELOPING A REPERTOIRE OF ACTIVITIES FOR TEACHING PHYSICAL SCIENCE

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In addition to Dr. Cathey's reviews, Troy Bridges, one of the most outstanding chemistry teachers in the state, has reviewed this manual for technical qualities. As a chemistry teacher at Spartanburg High School, Troy provided his students with unusual opportunities to conduct scientific research under his close supervision. Numerous honors have been won by his students at the South Carolina Junior Academy of Science, Junior Science and Humanities Symposium, and science fairs.

During the South Carolina Science Council Meeting held each year, sharing sessions are conducted where outstanding science supervisors and teachers demonstrate activities that they have found successful in explaining difficult concepts. I wish to thank Naomi Martin, Wyatt McDaniel, and Randy Mahaffey for sharing some of their tried and tested activities with their fellow science teachers. Several of these activities appear in this manual.

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Peggy W. Cain

PREFACE

For too long, physical science has been limited to the academically more able students, even though many of its concepts are essential to the scientific literacy required of all citizens today. Many principles in physical science are difficult for students to understand unless they see them illustrated through concrete examples. However, what students may not be able to grasp by reading and reciting, they can understand if given the opportunity to observe, compare, predict and interpret.

This collection of physical science activities has been written to aid science teachers in using a repertoire of instructional strategies that should not only capture student interest and curiosity but also will enable all students to learn the basics of physical science. Teaching physical science through these activities will develop in students the ability to draw their own conclusions by hypothesizing and experimenting. Through practical applications, they will be able to relate these principles to real life situations, since the activities themselves have been chosen to represent those scientific processes most commonly encountered in industry, trades, health, and household.

Research has determined that the most important variable in a classroom is the teacher. Between seven hundred and three thousand decisions must be made daily by the teacher in order to provide the students with the most efficient, effective, and relevant strategies for learning. It takes a tremendous amount of preplanning for a teacher to maximize learning outcomes. It is up to the teacher to utilize the time available in the classroom to increase the amount of academic engagement or time-on-task for the student. Science teachers need to explain concepts through examples and modeling activities that involve the learner. The content in this manual has been selected from tried and tested activities that match the learner's interest, ability, and experiences.

Research for effective science classrooms has shown that prior to the start of a unit teachers must formulate an instructional objective and communicate it to the students. The plan to teach the objective must be carefully orchestrated by the teachers so that the attention of the learner is focused on the objective and maintained throughout the lesson. This can be accomplished by involving the learner.

The use of this repertoire of activities can easily aid the science teacher to focus the learner's attention on the lesson. This can take the form of quick activities, demonstrations, and laboratory exercises that capture the curiosity and interest of the students and prepare them for learning at the start of the unit or daily lesson. Applications can be used to relate learning to past, present, and future experiences of the learner. Proper questioning techniques can also be utilized to maintain the focus on the lesson. Remember, for learning to take place the learner must become involved in the lesson.

Monitoring the progress of the learner and adjusting if necessary are other aspects of teaching strategies that must be planned. The learner's prior experiences and ability will dictate the teacher's necessity to adjust techniques daily. The principles of learning that include motivation, reinforcement, retention, and transfer must be utilized at all times.

It will be up to the teacher to provide opportunities for the learner to utilize high level cognitive skills. Knowledge level utilizes simple recall of specific facts and does not stimulate higher order thinking. The activities in this manual can be used by the teacher to achieve thinking on all levels.

Comprehension level thinking can be taught by having the students describe in their own words, predict, and summarize the results of the activity. Identifying applications of the concepts in everyday situations can make the learning more relevant. Analyzing involves breaking down the material into its components while synthesizing involves putting the elements together to form a pattern or perhaps create a new hypothesis. Teachers must plan lessons utilizing different levels of thinking for the most effective instruction.

Many personal qualities such as enthusiasm, dedication, and interest in the students must be exhibited by the teachers. This must be coupled with preplanning of instructional strategies. Research has indicated that increased student achievement is dependent on the use of pre-instructional organization. An instructional plan must be utilized if the understanding of science concepts is to be within the grasp of all students. It is to this purpose that this publication has been developed.

HOW TO USE THIS ACTIVITY MANUAL

The framework for this physical science course is found in the "Outline of High School Credit Courses." The objectives followed in this manual correlate with the topics listed under Physical Science: General* and printed by the South Carolina Department of Education in 1984. For each of the fifteen major units, there is at least one practical application activity for the students to investigate relating the concept to everyday experiences. This is illustrated below.

	PRINCIPLES		PRACTICAL APPLICATIONS
1.	The nature of science	1.	Devise and conduct a controlled experiment with only one variable.
2.	Measurements	2.	Compare metric and English units used to measure the engine capacity and repair tools for automobiles and motorcycles.
3.	Properties of matter	3.	Analyze the methods used to measure strengths of antifreeze used in automobile and truck radiators.
		4.	Determine the methods used to prepare soaps, detergents, cold creams, hand lotions, tooth pastes, athlete's foot powders, deodorant liquids, and lipsticks.
4.	Energy	5.	Trace the energy changes from one form to another in an automobile, television, computer, nuclear power plant, or school heating system.
5.	Atomic structure	6.	Identify elements with diffraction grating.
6.	Chemical reactions	7.	Analyze the process involved in the manufacture of lime, mortar, plaster, cement, and concrete.

To assist the teacher in planning, each unit is divided into components which include:

OBJECTIVE

This is a statement of learning that identifies explicitly what skills and knowledge the learner will be able to demonstrate at the conclusion of instruction. The objective stated at the beginning of each unit may be broken down into smaller pieces so that one is clearly stated at the beginning of each lesson.

*See Appendix for the complete outline of the Physical Science: General course.

TEACHING STRATEGIES

The objective is followed by the teaching strategies that provide background information for the concepts. In addition the activities are grouped so that the organization of the lessons can flow smoothly.

ACTIVITIES

Directions are outlined for a variety of demonstrations, individual and guided activities, along with laboratory experiences. Each explains a concept by the use of visual, tactile, auditory, and kinesthetic teaching/learning styles.

APPLICATIONS AND IMPLEMENTATION

Present, past, and future experiences of the students are related to the concepts demonstrated in the activities. In addition many other suggestions are outlined that extend the concepts observed to other applications.

The need has been apparent for a course designed to give the average student a background in practical applications of science concepts. Therefore, this activity manual has been organized around basic physical science principles correlated with technical applications used in trades, industry, and health-related fields.

SAFETY SUGGESTIONS

A well planned science lesson includes planning for classroom safety. There are many sources for safety procedures. One available from the South Carolina Department of Education is the "Handbook for Safety Education K-12."* In addition to this publication, all of the science textbooks have a section usually found in the teacher's edition that lists good safety procedures. The South Carolina Department of Education also stipulates safety procedures in the Defined Minimum Program that require the use of eye protective devices when students are working with something that could be considered explosive, or whenever there is a danger or threat to the eyes. These recommended practices should be reviewed frequently.

A positive attitude towards safety on the part of the students is imparted to them by the attitude of the teacher. Just as a mathematics teacher should never attempt to solve a problem without having worked it beforehand, a good science teacher should never allow students to perform a laboratory activity before this activity has been tried and potential dangers have been identified. Students should never be permitted to perform unauthorized experiments.

One good rule to follow that will eliminate many of the possible accidents in the classroom is for the teacher never to leave the room under any circumstances during a laboratory activity. Students should be supervised at all times. Another good policy is to leave out on the lab desk only the chemicals and equipment that are to be used for the specific experiment that the students are performing. Once the laboratory activities have been completed, all materials should be placed in a suitable locked storage room. It is also important for the teacher when performing a demonstration/experiment to identify good safety procedures and follow these explicitly. During the course, it should be instilled in the students to follow certain procedures and eliminate possible dangers while enjoying these laboratory experiences. Research has proven that activities, demonstrations, and lab exercises are the best way for students to gain an understanding of science concepts.

*Available from South Carolina Department of Education,
Curriculum Development Section, Rutledge Building,
Columbia, South Carolina 29201.

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Course Outline for Physical Science: General 119

UNIT I
THE NATURE OF SCIENCE

OBJECTIVE

The students will demonstrate the ability to devise and conduct a controlled experiment measuring the effect of changing one variable at a time. They will observe that, as a result of this experiment, other variables will change.

TEACHING STRATEGIES

Science received its greatest impetus in the sixteenth century when man began to ask questions about nature and resolved the answers with experiments rather than merely using logic. The scientific method is used to determine hypotheses, theories, and laws. It is a way of thinking that requires many skills such as observing, comparing, measuring, communicating, and collecting data. Using these skills, scientists recognize definite observable facts and draw a conclusion or form a hypothesis by inferring, interpreting data and predicting. The hypothesis must be testable; that is, it can be proven or disproven by setting up a controlled experiment. Only after a hypothesis or theory has survived repeated testing does it become a law. Scientific laws are derived by generalizations of theories and identifying phenomena where there have been no known deviations. Of course, mathematics must be involved in all experimental work.

The man credited as being the father of the scientific method of thinking was Galileo Galilei, an Italian who grew up in Pisa. He introduced the technique of using an experiment to prove his ideas. You may have heard about the famous experiment where he dropped two balls of different masses from the Leaning Tower of Pisa to prove that objects fall at the same rate. Even though there is some question about the authenticity of the event, this period in history marked the beginning of scientific experiments being devised to prove a theory.

Galileo developed the law of the pendulums when he was only twenty. He timed the swing of the lamp in the cathedral at Pisa and came to several conclusions. He noticed that the swing took the same time whether the arc was large or small. In the activity PENDULUMS, the students will experiment with pendulums to see how the size of the pendulum bob, length of the string, and arc affects the time for the swing.

Galileo did not have a digital watch or even a wind up clock, so he used his pulse to time the swing of the lamp in the cathedral. This led to his suggestion that the pendulum be used to take the pulse of patients.

Perhaps the most famous pendulum is the Foucault pendulum, used as a way of demonstrating that the earth was rotating on its axis. Today these pendulums are found in many museums across the country. For the Foucault pendulum to swing on its own, a long wire must be attached to the ceiling or dome of a three of four story building with a heavy metal ball attached to the other end. After it is set in motion, a drive system keeps it swinging. The only forces acting on the pendulum are the forces of gravity and the little bit of air resistance that slows down the pendulum. Most of the Foucault pendulums have a magnet that gives the pendulum a little kick to keep it moving. Is there one in South Carolina? (Clemson University) Many of the Foucault pendulums in museums are used as time pieces and have pegs or dumbbells that are knocked over each hour. Find out if your students have seen a Foucault pendulum.

There are many experiments that can be used to illustrate the scientific method. The activity on pendulums is merely a suggestion. What is important is that the students learn how to set up an experiment using only one input variable at a time, in such a way that they can record measurements to determine which variable changes.

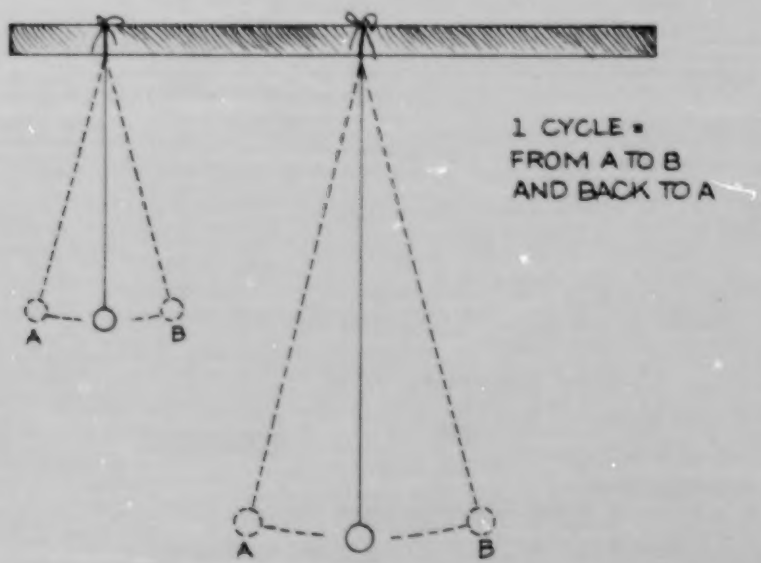
ACTIVITIES

- **Pendulums**

Before starting this activity, have a pendulum set up in the classroom. As you swing the pendulum, ask the students to come up with all the factors that they think control the motion of the pendulum bob (e.g., size of bob, length of string, size of arc). Once they have determined the variables and how to measure each variable, let them begin the activity to test how much the variables affect the motion of the pendulum.

The equipment necessary for this experiment is very simple. You'll need two nuts, one large and one small; a piece of fishing string about 2 meters long; a support to hold the pendulum (the desk will be fine); and a clock with a sweep second hand or stopwatch for each pair of students. Make copies of the following page or a similar sheet for students to record the data.

The students should conduct the experiment, testing for only one variable at a time. Have them determine if the size of the bob affects the motion of the pendulum. Next have them vary the length of the pendulum. Now have them determine if the size of the arc affects the motion of the pendulum. Remember an extremely large arc will not work. When taking the data, a complete cycle will be from A to B and back to A.



Suggested Data Table:

PENDULUMS

Allowing the mass of the bob to vary.

Time for 15 Cycles (15 complete vibrations) (Seconds)	Size of pendulum bob
Large Bob	
Small Bob	

Allowing the length of string to vary.

Length of string (cm)	Time for 15 Cycles (Seconds)
25 cm	
50 cm	
100 cm	

Allowing the size of the arc to vary.

Size of the Arc (degrees)	Time for 15 Cycles (Seconds)
5 degrees	
20 degrees	

Let students discuss and compare their data to determine how each variable affects the motion of the pendulum.

What effect does the mass of the bob have on the period of the pendulum?

What effect does the length of the string have on the period of the pendulum?

What effect does the size of the arc have on the pendulum?

What hypotheses can be made about the pendulum?

Compare these to the Laws of the Pendulum.

APPLICATIONS AND IMPLEMENTATION OF THE EXPERIMENTAL NATURE OF SCIENCE

Now that students have conducted an experiment on their own, they should have a much better understanding of the scientific method. Many natural phenomena have been solved by conclusions derived from experimental data. You can think of Columbus' voyage to the new world as a test of the hypothesis that the earth was round. It was not until airplane flights that we actually saw that the earth was round even though the flat earth theory had been discarded centuries ago because of experiments such as the Foucault pendulum.

Some examples that have been accepted are the germ theory of disease, universal gravitation, and duality of light. These are but a few of the major theories that have been derived by man and have withstood repeated testing.

It might be interesting to note that Roger Bacon, the famous English author, is reported to have died because of an experiment. He was proving that a chicken could be preserved by freezing it in the snow. He plucked a chicken and buried it in the snow. Unfortunately, he caught cold and died of pneumonia while doing this experiment. Nevertheless, he was conducting an experiment based on a theory.

The experimental nature of science means that it is in a state of constant revision. It is always possible that a theory which has withstood previous testing may eventually be disproven. Students must learn how scientists think and why scientific experiments are conducted according to rules and explicit procedures. Students must understand the experimental nature of science which begins with a theory. After a great deal of testing, it progresses to the hypothesis stage. Upon repeated verification of test results, it becomes a law.

UNIT II
METRIC MEASUREMENTS

OBJECTIVE

The students will demonstrate the ability to conceptualize metric units by making comparisons with English units enabling them to **THINK METRICALLY**.

TEACHING STRATEGIES

Metric units must be used and comparisons made before students can understand the metric system and feel comfortable using it in everyday situations. The students will have to learn to **THINK METRICALLY.** Ask them how big they think a centimeter is. How long is a meter? What has the mass of a gram? Do they get more milk in a liter or a quart? Be careful not to have them convert from one system to another. Instead, have the students form the concept relationships by making comparisons.

The decimeter box is an excellent tool for demonstrating the relationship between linear, volume, and mass units and also the derivation of the liter and kilogram from the linear measurements.

Be sure to explain the metric units by doing the activity WHAT'S SO IMPORTANT ABOUT A DECIMETER BOX? Next, make metric and English unit comparisons between linear, mass, and volume measurements by using commonly found items. HOW DOES THE METRIC SYSTEM COMPARE? gives plenty of ideas for comparisons between the metric and English units. Always make comparisons by using one whole metric unit equal to the English equivalent.

e.g. 1 meter = 39.37 inches

1 liter = 1.06 quarts

1 kilometer = 0.6 miles

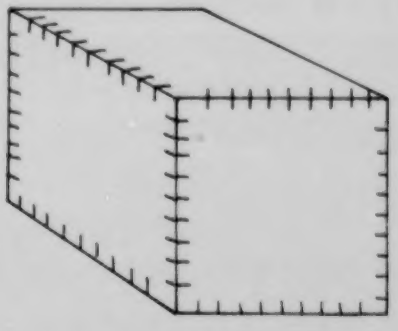
Be careful not to convert from one system to another; but instead, have the students form the concept of the relationship by making comparisons between the metric and English units. This should be followed by HOW GOOD ARE YOU AT PREDICTING? where the students estimate their height and weight measurements before actually making measurements. If possible, make a metric cubic meter as outlined in HOW LARGE IS A CUBIC METER?

Students will have to learn how to convert within the metric system. STAIR STEP METRIC PREFIXES! demonstrates an excellent technique to teach size relationship of metric units. Metric units must be reviewed frequently during the course so students can become familiar with these units and **THINK METRICALLY.**

ACTIVITIES

- **What's So Important About a Decimeter Box?**

A decimeter box is essential for conceptualizing metric units. If one is not available, have the school shop make a wooden box 10 cm X 10 cm X 10 cm, leaving the top open, or have the students make paper decimeter boxes. Measure the length, width, and height to determine the volume in cubic centimeters. Have the students visualize the volume of the decimeter box by pouring 1 liter of water or sand in it, depending on the type of box you have. Next, take the mass of 1 liter of water. This will provide an opportunity for the students to realize that the linear measurement of 1000 cubic centimeters has the volume of 1000 milliliters (1 liter), which has the mass of 1 kilogram.



Line the decimeter box with a plastic bread bag, then pour in 1 liter of water from a soft drink bottle. Hold this bag up so that the students can visualize a liter.

1000 cubic centimers has the volume of 1000 milliliters and contains 1 kilogram of water at 4°C

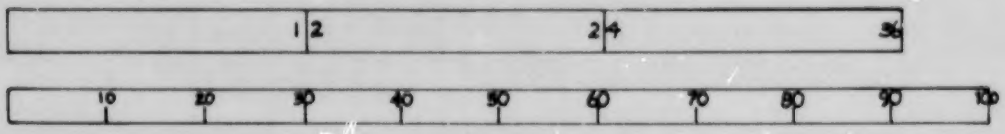
or

1 cubic centimer has the volume of 1 milliliter and contains 1 gram of water at 4°C

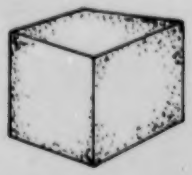
- **How Does the Metric System Compare?**

Make the following comparisons of commonly found items. Make a collection of as many of these items as possible and actually make measurements by comparing:

A yard stick and a meter stick,

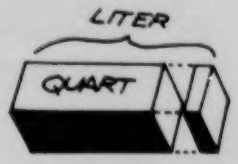


A cubic centimer to a cube of sugar,
1 sugar cube = 1 cubic centimeter



The mass of an M & M to a gram,
1 M & M = mass of 1 gram

A liter soft drink container to a quart milk carton,
1 liter = 1 quart and a little bit more



A nickel to 5 grams,

Spent rifle and pistol shells such as 9mm
cartridge with a 38 caliber
(A 38 caliber is about 0.38 inches in diameter),

The sizes of 35mm, 16mm and 8mm film on a metric ruler,

The diameter of the head of a thumb tack to 1 centimeter,

The wire of a paper clip to 1mm,

Miss America's measurements to Miss Universe,

Distance from your school to Myrtle Beach in kilometers and miles,

Thermometer scales,

Body temperature in both metric and English systems,

Boiling and freezing points of water,

Room temperature in both metric and English units,

Freezing of Oxygen and Nitrogen on both Fahrenheit and Celsius
temperature scales,

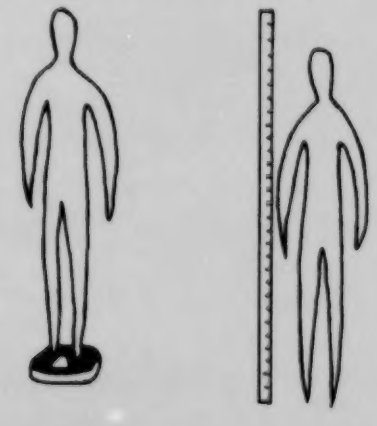
Olympic game measurements to school track and field events.

- **How Good Are You at Predicting?**

Have individual students predict or estimate several measurements followed by actually making these measurements:

Their own height,

Their own mass,
(Note this is not weight. In the metric system, mass is used as a quantitative measure of inertia that a body contains. Inertia is the amount of resistance an object has to motion while weight is used in the English system to measure the force of gravity.)



Estimate:

Number of square meters in the classroom floor,

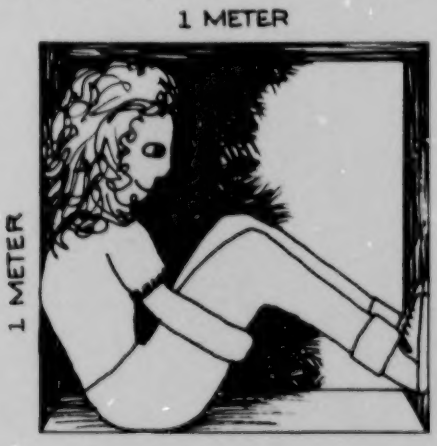
Volume of air in the classroom,

Volume of water needed for a swimming pool in metric units, and

Number of kilometers to Myrtle Beach.

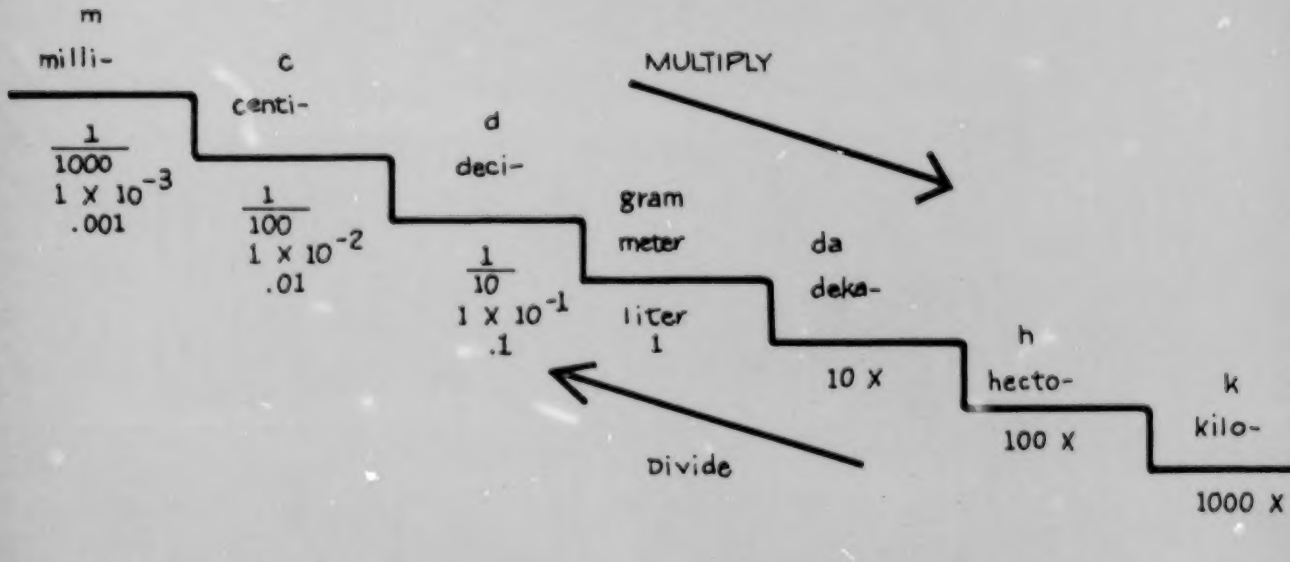
- **How Large Is a Cubic Meter?**

Locate a large cardboard box the size of a cubic meter (refrigerator or packaging carton) or use slats to make the frame of a cube with 1 meter sides. The students can then make actual measurements. To dramatize the size of a cubic meter, have the students crawl inside.



- **Stair Step Metric Prefixes!**

Convert units within the metric system by using the stair step diagram. To convert, divide by 10 as you go up the stairs and multiply by 10 as you go down.



The stair step diagram will help the students conceptualize the sequence of size relationship between the units in the metric system. Students will have to be given many examples to practice using this system so that they can become very efficient in converting units within the metric system.

APPLICATIONS AND IMPLEMENTATION OF THE METRIC SYSTEM

Through the use of metric units, the students will become familiar with the system so that they will **THINK METRICALLY.** In order for them to do this, they must become familiar with the metric system well enough to transfer the traditional thinking in English units to the metric units. Once the students are accustomed to using metric units, have them investigate the type of metric tools that are used to repair motorcycles and automobiles. How much difference is there between a ½ inch and a 13 mm wrench? How is the cubic displacement of engines measured? Does the speedometer in your car register in both miles/hour and kilometers/hour?

Metric units must be reviewed frequently during the course, so that the students can become familiar with these units and **THINK METRICALLY.**

UNIT III
PROPERTIES OF MATTER

OBJECTIVE

The students will be able to compare the different properties of matter by measuring density, specific gravity, and buoyancy.

TEACHING STRATEGIES

Properties of matter can best be understood by actually making measurements and observing chemical and physical changes. Some of these activities can be accomplished through demonstrations while others are better understood by the student with hands-on experiences.

Man has learned to identify matter by asking questions about specific properties. Does it have a color, odor, or taste? What is the density? How does the density of matter compare to that of air or water? What is its specific gravity? Does it float or have buoyancy?

In these activities the students first make observations about the differences in densities, then quantitative measurements will be made. WHICH IS HEAVIER, OIL OR WATER?, WHICH WEIGHS MORE, A POUND OF LEAD OR A POUND OF FEATHERS (CORK)?, A ROCK THAT FLOATS!, and CHANGING DENSITIES! will help the students recognize the differences in densities by observing oil floating on water; lifting equal volumes of lead, aluminum, and cork; seeing a rock float; and observing the moth balls change densities as a gas collects on the surface through a chemical change. Quantitative measurements will be made of solids and liquids in DOES THE DENSITY OF WOOD VARY?, DENSITY BY WATER DISPLACMENT!, and DENSITY OF LIQUIDS. If the students cannot handle the mathematics, allow them to use pocket calculators. This will add interest to the lesson.

Comparing the density of solids and liquids to water is another concept that needs to be reinforced by hands-on activites. The specific gravity activities are DETERMINING THE SPECIFIC GRAVITY and MAKING SPECIFIC GRAVITY MEASUREMENTS. Through the activity WILL CLAY FLOAT?, students will be able to relate the property of buoyancy of objects to density and specific gravity. This activity will help the students figure out what makes a metal ship float, even though the density of the metal is greater than that of water.

ACTIVITIES

- **Which Is Heavier, Oil or Water?**

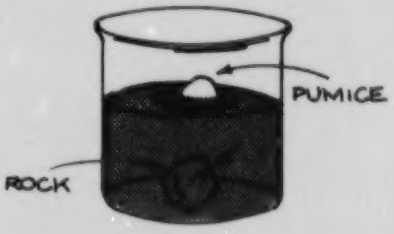
Compare the density of water and oil by pouring 20 ml of water over 20 ml of motor oil in a graduated cylinder. Which liquid rises to the top? (Oil) Which liquid has the greatest density? (Water) After a rain, why do you see a thin film of oil on water puddles in busy streets? If milk is not homogenized, which rises to the top: the milk or the cream? Which has the greatest density? (Milk)

- **Which Weighs More, a Pound of Lead or a Pound of Feathers (Cork)?**

Provide the students with an opportunity to lift equal volumes of lead, iron, aluminum, and cork. Density sets are excellent for this activity. By handling these samples they will be able to determine the differencs in density without making mathematical calculations.

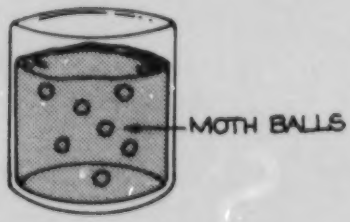
- **A Rock That Floats!**

Obtain a piece of pumice (a volcanic rock) and another rock like granite about the same size. Demonstrate that the pumice can float by thrusting both rocks in a pan of water. Why does the pumice float? (The pumice is full of gas bubbles.) Are there any other rocks that can float?



- **Changing Densities!**

By adding vinegar to moth balls that have been placed in a baking soda solution, you can illustrate changing densities. This will make a better demonstration than hands-on activity. You'll need moth balls (napthalene), baking soda, vinegar, and a large beaker or peanut butter jar. Dissolve the baking soda in the water until the moth balls begin to sink very slowly. Pour in some vinegar and stir slightly. Why are the moth balls rising to the surface? (A gas, carbon dioxide, forms bubbles on the surface of the moth balls making the moth balls plus the bubbles lighter than the solution.) Why do the moth balls sink? (When the moth balls are covered with bubbles, more volume is occupied thus temporarily decreasing the density of the moth balls including the bubbles. When this happens, the moth balls rise to the surface of the water and float. As some of the bubbles are lost, the moth balls plus the remaining bubbles increase the effective density and begin to sink. This is repeated as the moth balls rise and fall.) How is the gas formed that gathers on the moth balls? (The acid vinegar and alkaline baking soda, sodium bicarbonate, combine and release carbon dioxide.) Make this demonstration more dramatic by adding food coloring.



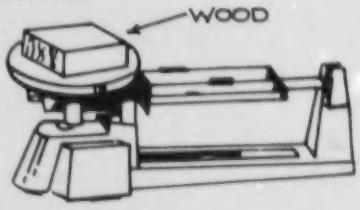
- **Does the Density of Wood Vary?**

Is hardwood heavier than pine? Using metric units, determine the density of a variety of wooden blocks cut from different trees. Make linear measurements of length, width, and height to compute the volume.

The length (l) times the width (w) times the height (h) equal the volume:

Length X width X height = volume

Take the mass of each block then substitute in the formula:



$$\text{Density} = \frac{\text{Mass}_{(\text{grams})}}{\text{Volume}_{(\text{cubic centimeters})}}$$

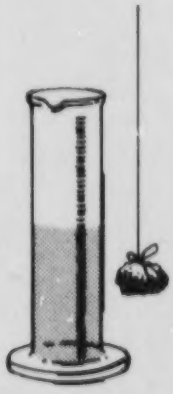
Separate the blocks into hardwood and softwood. Which trees grow faster, hardwood or softwood? Is green wood heavier than dry wood? What are the units for density? (g/cm^3)

- **Density by Water Displacement!**

Determine the density of irregularly shaped pieces of granite in metric units using the water displacement method. This is done by measuring the mass of the granite on a balance pan. Next determine the volume of the granite by placing it in a graduated cylinder partly filled with water. Take the volume measurement of the water before and after the granite has been added. The difference between these measurements will be the volume of the granite. Substitute the mass and the volume of granite in the density formula.

$$\text{Density} = \frac{\text{Mass}_{(\text{Granite in grams})}}{\text{Volume}_{(\text{Granite + water in ml})} - \text{Volume}_{(\text{Water in ml})}}$$

What are your units for density? (g/ml) What units are used for density in most tables? (g/cm3). Convert the milliliters to cubic centimeters as 1 ml = cm^3. What are your new units for density? (g/cm^3) Can you use this method to determine the density of other irregularly shaped solids? (yes)



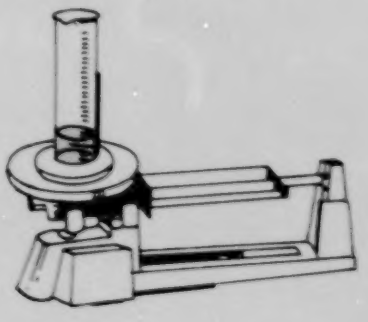
- **Density of Liquids**

Determine the density of motor oil, isopropyl alcohol, and water by using a graduated cylinder and balance. You will need to take the mass of the graduated cylinder before and after adding each liquid. The difference between these two masses will be the mass of the liquid. The volume can be determined by reading the level of each liquid in the graduated cylinder. Then substitute the mass and volume of each liquid into the density formula and calculate your experimental value for the density.

$$\text{Density} = \frac{\text{Mass}_{\text{(Motor oil in grams)}}}{\text{Volume}_{\text{(Motor oil in ml)}}}$$

Convert millimeters to cubic centimeters as 1 ml = 1 cm^3.

What are the units for density of liquids? (g/cm^3) Are density units always the same? Do you use the same density units for liquids and solids? (Yes) What is the density of water? (1 gram/cubic centimeter) Which liquids are denser than water? (Mercury, sea water, glycerin, and carbon tetrachloride) What are the liquids lighter (less dense) than water? (Gasoline, motor oil, and isopropyl alcohol)



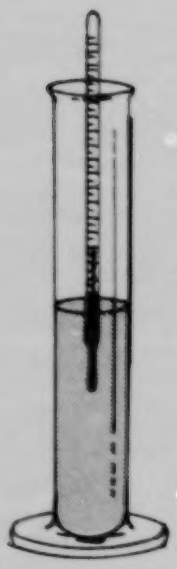
- **Determining the Specific Gravity**

When you compare the density of a solid or liquid to that of water, it is called specific gravity. This is the ratio of the density to that of water. Determine the density of granite by using the water displacement method explained in DENSITY BY WATER DISPLACEMENT! Now compare the density of water, 1 gram/cubic centimeter, to the density of the granite. This is done by dividing the density of the rock by the density of water, 1 g/cm^3.

$$\text{Specific Gravity} = \frac{\text{Density}_{\text{(rock in g/cm}^3\text{)}}}{\text{Density}_{\text{(water in g/cm}^3\text{)}}}$$

What is the specific gravity of the granite? Compare this to the value on a table of specific gravities. What is the unit for specific gravity? (It is a ratio of numbers and therefore has no units.)

- **Making Specific Gravity Measurements**



A hydrometer has been specially designed to measure the density of liquids by its ability to float. This instrument has been weighted with lead so that it floats vertically. A scale is calibrated on the side so that you can read the density of the liquid. The denser the liquid the higher the density of the liquid. The denser the liquid the higher the hydrometer floats. One hydrometer is calibrated for liquids with a density less than water and one for liquids with a density greater than water. Use the hydrometer to measure the specific gravity of liquids that are lighter than water such as antifreeze, isopropyl alcohol, and water.

What is the unit for specific gravity? (It is a ratio of numbers and therefore has no units.)

- **Will Clay Float?**

Ask the students to drop a ball of clay in a container of water. What happened to the clay ball? (It sank to the bottom of the container.) Now ask them to fashion a piece of clay so that it will float. What shape must the clay have in order to float? (Shape of a cup) Why do ships that are made out of steel float? (It is the shape or design of the ship. The amount of water displaced by the ship must have a greater mass than the steel ship.) Apply Archimedes' Principle. This states that the buoyancy of an object is dependent upon the mass of the liquid that the object displaces. (The ship must be designed so that its mass is less than the amount of water that it displaces.) About how much water does the clay boat displace? What is the mass of the water displaced? What happens to the water line of a ship when it is loaded with cargo? (The boat sinks lower in the water depending upon the amount of cargo.) Ask your students to design a concrete boat.

APPLICATIONS AND IMPLEMENTATION OF THE USE OF DENSITIES

There is evidence of the differences in densities all around us even when you buy health food store peanut butter. An example is the layer of oil that accumulates on top of the peanut butter spread. Densities can be used to determine the charge on a battery or the amount of antifreeze in the radiator. At the filling station, the attendant determines the charge stored in the battery by measuring the density of the acid. A small amount of the battery acid is removed from the battery with a suction bulb. A small hydrometer floats in the liquid. The depth of the hydrometer floating in the liquid determines the density of the liquid which correlates with the amount of charge on the battery.

When you want to know if there is enough antifreeze in the car radiator, then another type of hydrometer is used to take the density of this liquid. These very inexpensive instruments are made with small balls the size of BB shots that have slightly different densities. Each ball floats at a different level depending on the strength of the antifreeze. By counting the number of balls floating, the amount of the antifreeze is determined. Obtain several types of hydrometers so the students can take measurements in the classroom.

UNIT IV
ENERGY

OBJECTIVE

The students will demonstrate the ability to recognize energy as it is transformed from one form to another using the principle of energy conservation.

TEACHING STRATEGIES

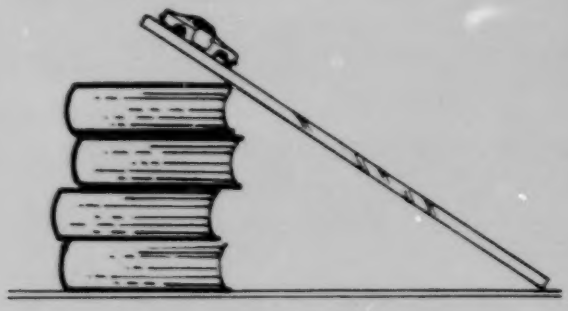
Matter has mass and occupies space. On the other hand, energy cannot be seen, felt, or smelled. Therefore, it is much harder to understand the concepts associated with energy than matter. This is because matter is tangible. You can see and move it. However, energy is abstract and is the mover of objects. There are two kinds of energy, potential and kinetic. Potential energy is related to position and kinetic is energy of motion. RELATING POTENTIAL ENERGY TO KINETIC ENERGY, ENERGY OF A PILE DRIVER, and ENERGY OF THE LOOP-THE-LOOP will demonstrate how energy is dependent on height or position.

Energy is a combination of physical properties and interactions between familiar forms such as heat, light, electricity, or nuclear. These forms of energy move matter from one place to another or change matter from one substance to another. This is demonstrated in ENERGY TRANSFER THROUGH SYMPATHETIC VIBRATIONS. It also can be transformed from one form to another. For instance mechanical energy can be transformed into heat energy. What happens when you hammer a nail into a board? (The nail becomes warm.) Chemical energy turns into electrical energy in an automobile storage battery. Chemical energy can be turned into heat energy when wood is burned or when the chemicals combine to form heat as demonstrated in CHEMICAL ENERGY TO HEAT ENERGY.

ACTIVITIES

- **Relating Potential Energy to Kinetic Energy**

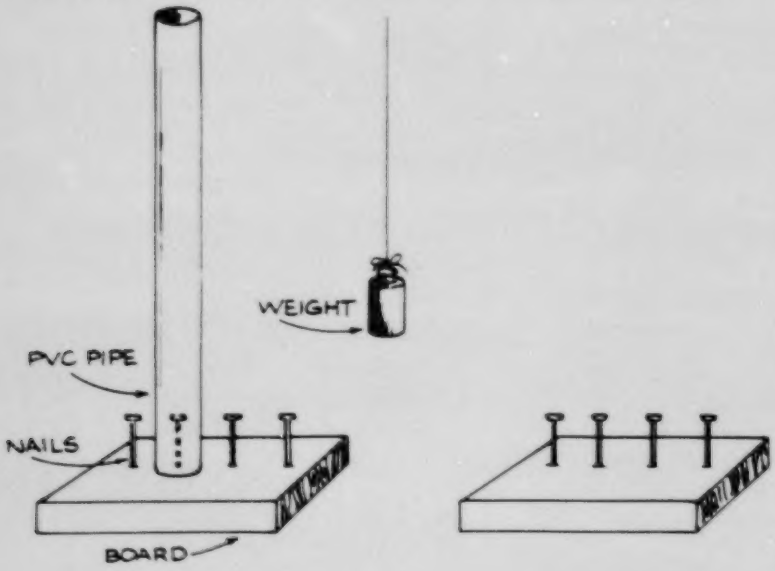
A toy car, an incline plane made with a board, and a couple of books will be enough equipment to demonstrate the difference between potential and kinetic energy. Hold the toy car at the top of the inclined plane. At this point, the car has potential energy but no kinetic energy. As the car is turned loose the potential energy becomes kinetic energy or energy of motion. Now change the incline plane so that the effect of height can be visually recognized. The greater the height the larger the kinetic energy of the car and the faster it goes at the bottom of the incline.



- **Energy of a Pile Driver**

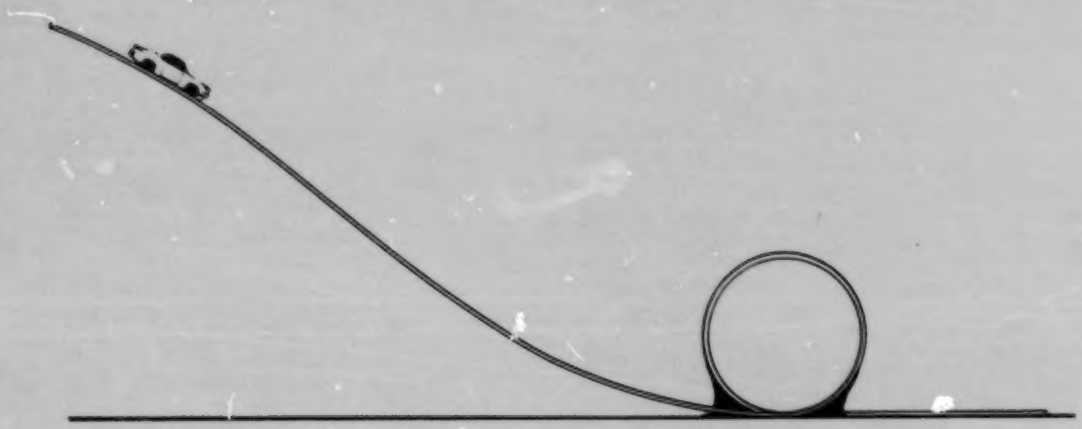
To make a pile driver that will demonstrate the amount of energy that will be obtained from dropping different masses, you'll need a mailing tube or PVC pipe about 1 meter long; 2 pieces of 2 by 4 lumber about 30 centimeters long; 8 nails; 100g, 200g, and 500g weights; and a centimeter ruler. Drive 4 nails in each board just a few centimeters. The nails should all be the same height. Use the first nail as the control. Then hold the tube over the nails and drop the 100g, 200g and 500g weights on each one of the nails respectively. Measure the height of all 4 nails. What conclusions can you draw from the size of the masses you dropped and the depth the nails are driven? Which mass has the greatest potential energy?

Use the other board for dropping the masses from different heights. Keep the first nail as a control. What is the conclusion that can be drawn from dropping different size masses? (The larger the mass, the greater the energy.) Which mass has the greatest potential energy? (The largest mass dropped from the greatest height, P.E. = mgh) Which mass produced the largest kinetic energy? (The largest mass dropped from the greatest height developed the most kinetic energy, K.E. = $\frac{1}{2}mv^2$.) What part did height play in the amount of energy of the masses? (The greater the height, the larger the velocity and the greater the kinetic energy)



- **Energy of the Loop-the-Loop**

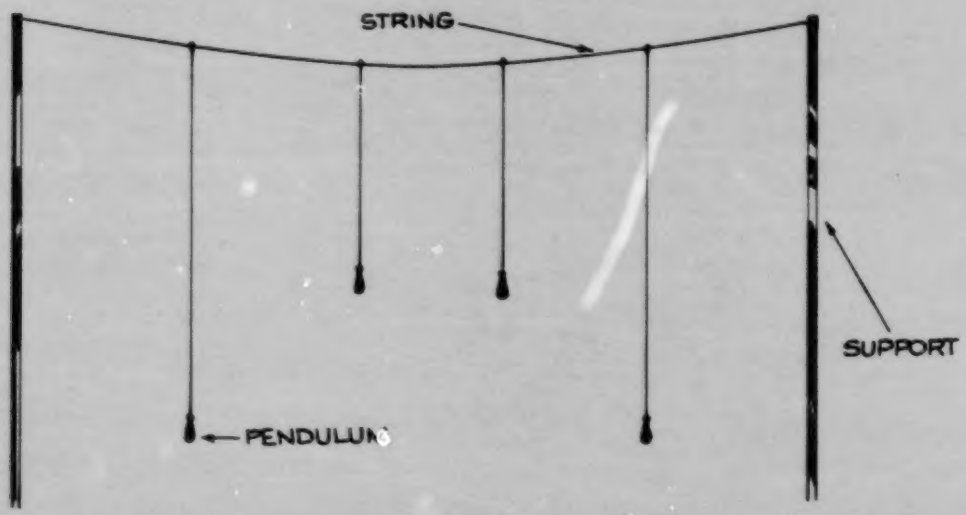
The loop-the-loop hot wheels toy makes an excellent demonstration of the transfer from potential to kinetic energy through conservation of energy. The hot wheels car poised at the beginning of the track will have potential energy but no kinetic energy. The energy at the bottom of the loop will be all kinetic energy and will be equal to the potential energy at the top. All the energy in between the two places will be constantly transferring from potential energy to kinetic energy. At any point the addition of the potential energy and the kinetic energy will equal the amount of potential energy of the car at the beginning or the kinetic energy at the end. This is called "Conservation of Energy."



- **Energy Transfer Through Sympathetic Vibrations**

Energy is often transferred from one object to another. In this activity the students will be able to see the motion of one pendulum bob slow down and then transfer to the other pendulum bob. You'll need about 5-6 meters of string, 4 pendulum bobs or fishing weights, 2 supports and a meter stick. Assemble the materials according to the diagram. Be sure to make two sets of pendulums with equal lengths. Now set one of the pendulum bobs in motion. In a few minutes the other pendulum of equal length will begin to swing as the first one dissipates. Wait a few minutes as the energy is transferred back and forth between the pendulums of equal length. Is the energy transferred from the long pendulum to the short pendulum? (No) The sympathetic vibrations are transferred only to the pendulum of equal length.

This can be related to drums in a band vibrating as a result of other sympathetic sounds. Often cars develop rattles at certain speeds. This is also caused by sympathetic vibrations.



- **Chemical Energy to Heat Energy**

Combine a few pieces of mossy zinc with dilute sulfuric acid. After a few minutes have the students feel the bottom of the flask. When the chemicals zinc and sulfuric acid combine, heat energy is formed. Chemical energy has been changed to heat energy.

APPLICATIONS AND IMPLEMENTATION OF ENERGY TRANSFORMATION

Energy exists in two different forms. The energy that is stored in coal or in the water at the top of a dam is potential. The energy that exerts a force because of motion is called kinetic. Examples of kinetic energy are falling water, the masses in the pile driver dropping on the nails, or the motion of the hot wheels moving along the track. The sympathetic vibration of the pendulums demonstrated the energy transfer.

Energy can change from one form to another. This was demonstrated by the heat energy emitted from the combination of mossy zinc and sulfuric acid. Ask the students to name as many energy transformations as possible. Some examples are: chemical energy in a battery changing to electrical energy, chemical energy in fuel changing to heat energy, chemical energy in gasoline changing to mechanical energy in an automobile engine, and heat energy of the sun changing to electrical energy through a solar cell.

Conservation of energy has been demonstrated in several ways. Energy never disappears; it is just transformed from one form to another. Once the students grasp an understanding of this transfer of energy, have them trace the energy changes from one form to another in an automobile, television, computer, nuclear power plant, coal power plant, or a school heating system.

UNIT V
ATOMIC STRUCTURE

OBJECTIVE

The students will demonstrate the ability to identify the difference between elements, compounds, and mixtures.

TEACHING STRATEGIES

The atomic theory was first proposed by John Dalton in 1830. There have been several modifications to his original theory but basically the theory still holds. Scientists have proven that all matter is made up of very small particles called atoms. Atoms of different elements are chemically different. Since Dalton's time, all but one of the 92 elements have been identified on the earth's surface. These elements are called the naturally occuring elements. Several more have been synthesized making a total of 107 elements so far to date.

IDENTIFYING ELEMENTS! using diffraction grating is an activity that must be done by all the students. Identification of elements by using these spectral lines has played a significant part in learning what elements are present in the cosmos.

Remember the smallest part of an element that retains all the characteristics of that element are atoms. The smallest part of a compound that retains all of the properties of that compound is called a molecule. A molecule is made up of two or more atoms. Mixtures are made up of a combination of elements and compounds that have been mixed mechanically without chemically combining.

In these activities, the students will become familiar with elements, compounds, and mixtures. In the activity ELEMENTARY MY DEAR WATSON!, the students will become familiar with elements that are present in their surroundings. FAMILIAR COMPOUNDS! will allow the students to recognize compounds that are found in and around the home. Mixtures will be investigated in MIXTURES ARE ALL AROUND US!, AUNT PEGGY'S COLD CREAM!, and SEPARATING OF MIXTURES USING CHROMATOGRAPHY! Other classic examples of mixtures are paint, tooth paste, air, baking powder, and milk.

ACTIVITIES

- **Identifying Elements!**

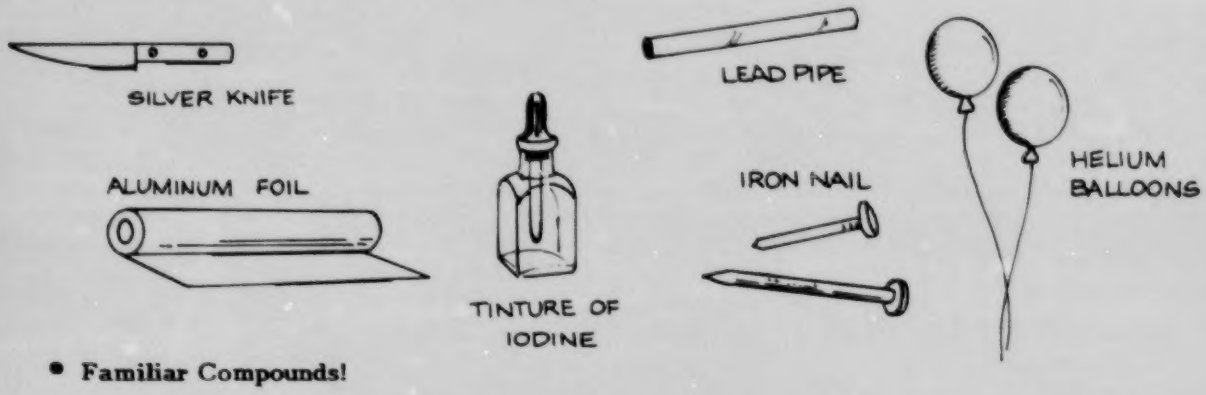
Identifying elements by characteristic spectral lines has been a tool frequently used by scientists. To demonstrate the spectrum of several elements, you will need a box of diffraction grating that can be obtained from a scientific company, several spectral tubes, and a power source for these tubes.

First, have the students look at the spectrum formed from an incandescent light bulb. Then have the students look at individual spectral tubes such as hydrogen, helium, and sodium. Compare what they have seen to the color plates found in many of the chemistry and physics textbooks. If possible look at the blue night light (mercury vapor) or yellowish lights (sodium vapor) found in most malls. Compare these spectral patterns.

Spectral analysis is a tool that is used by chemists in identifying elements. If possible take the class to a college or medical laboratory to see how spectrophotometers and mass spectrographs use this principle. Our understanding of the elements present in the universe are based on spectral analyses of various stars, nebula, and stellar clouds. Have the students look up red shift to find out how this is used to determine motion and velocity of stars and galaxies.

- **Elementary My Dear Watson!**

Assemble as many of the elements as possible that the students come in contact with daily (e.g., iron nail; copper pipe; gold jewlery; silver flatware; carbon in the form of coal, graphite, and diamonds; lead pipe; chromium plate from old car trim; and aluminum wrap). From the chemical storage room of the school lab assemble sulfur, magnesium ribbon, platinum wire, calcium turnings, and sodium. Of course you won't be able to see oxygen, nitrogen, and the inert gases that are present in the air, but maybe you can get a helium filled balloon and talk about the uses of these gases. Ask the students to determine a way to separate these into groups. Maybe someone will suggest metals and non-metals. Go over the major divisions on the periodic table between metals and non-metals. Now put these in groups according to the periodic families and compare properties.



- **Familiar Compounds!**

Collect as many compounds as possible in the surroundings. Ask the students to read labels on all the packages and cans at their home and surroundings to find other compounds. Some of these familiar compounds are:

Compound	Common name
Sucrose	as sugar
Sodium bicarbonate	as baking soda
Magnesium sulfate	as Epsom salt
Silicon dioxide	as sand
Magnesium hydroxide	as milk of magnesia
Acetic acid	as vinegar
Isopropyl alcohol	as rubbing alcohol
Calcium carbonate	as chalk
Hydrogen peroxide	as peroxide
Sodium chloride	as salt
Potassium chloride	as salt substitute
Sodium hydroxide	as lye
Carbon dioxide	as dry ice
Octane	as gasoline

Discuss the use of each compound. Ask the students to gather as many empty container boxes as possible for this activity and store them for future use. Add others to this collection as the students bring them to class. By reading the labels, the students will find many commonly used compounds. Make certain that the students understand that the elements in a compound have been chemically united and have a definite composition.

- **Mixtures Are All Around Us!**

Mixtures are chemicals that have not united chemically. There is no set formula for mixtures. A classic example of a mixture is granite. It is the bedrock for the piedmont and blue ridge geological areas of South Carolina. Granite is mined in South Carolina and is often used as gravel along railroad beds; therefore, samples can easily be provided for students to examine. In Fairfield County, the Winnsboro blue granite is mined for monuments and tomb stones.

Provide each pair of students with a magnifying lens and a piece of granite. Three different crystalline materials can be seen. These are quartz, feldspar, and mica. Make certain that the students identify each part of this mixture. Which material is shiny? (Mica) Which material is dark almost black? (Mica in the form of biotite) Which materials are light and almost clear or translucent? (Quartz and feldspar) If you have granite from different places, have the students compare the different proportions of quartz, feldspar, and mica in each sample as well as the difference in the size of the crystals.

Granite is a classic example of a mixture. Other examples are air, paint, the composition of the earth's surface, tincture of iodine, and tooth paste. Have the students research the composition of air, as well as the earth's surface.

- **Aunt Peggy's Cold Cream!**

Many products on the market resemble cold cream. Some are sold as skin softeners, skin cream, or beauty cream. These all serve the purpose of softening the skin, cleansing the skin, or protecting the skin against drying. Cold cream is a mixture of mixtures. That is, one mixture is suspended in another mixture forming a colloidal emulsion. Cold cream is mainly a combination of oils or waxes, water, sodium borate (borax), and perfume. It is important that this be done as a hands-on activity by students in small groups. Therefore, small portions are recommended for each group.

12	grams	Beeswax (scientific company or old drug stores)
56	grams	Mineral Oil
0.5	grams	Sodium borate (borax)
20	ml	Water
1-2	drops	Perfume
6-8		Empty cosmetic cream jars or baby food bottles with lids
2		Bunsen burners (or hot plates)
2		Ring stands and rings
2	squares	Wire gauze with ceramic center
3		Beakers (one pair to be used as a double boiler)
2		Stirring rods

While two students are preparing the beeswax and mineral oil, the other two students will prepare the water and sodium borate solution. Have two students cut the beeswax into small pieces. Then melt the beeswax using the double boiler method where one beaker with the beeswax is placed inside another beaker of boiling water. When the beeswax is melted, add the mineral oil. The other group of students will dissolve the sodium borate in water and bring the temperature to 80°C.

As soon as both groups are ready, slowly add the sodium borate solution to the melted wax and oil mixture stirring constantly. The students can take turns stirring. A colloidal suspension will form between these two mixtures. When the temperature drops to around 30°C or 40°C add a drop or two of perfume. Put the cold cream in empty cosmetic cream or baby food jars.

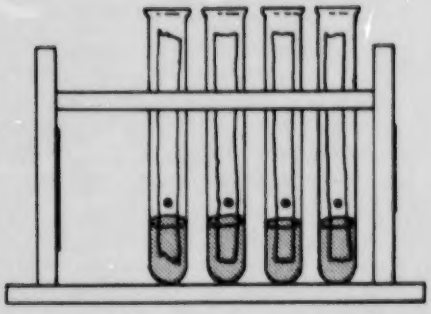
Have the students do a cost comparison between the cold cream they have just made and that found in a drug store or cosmetic catalog. Find out how Merle Norman, Max Factor, or Helena Rubinstein started out in the cosmetic business.

- **Separating Mixtures Using Chromatography!**

Separation of chemicals can be accomplished in a variety of ways. By using chromatography, a visual separation is apparent in just a few minutes. You'll need Whattman paper, several test tubes, isopropyl alcohol (rubbing alcohol), and felt tip pens in a variety of colors or a package of food coloring. For each pen you want to test, pour 5 ml of alcohol in the test tube. Cut the Whattman paper in strips 1 cm by 10 cm. Spot the paper with one of the pens about 3 cm from the end. Slide the strip of Whattman paper in the test tube so that it just reaches into the alcohol. Wait about 10-15 minutes. Follow this same procedure for each of the pens. If you use food dye, spot the paper with a small amount of the coloring by using a drop on a stirring rod or tooth pick.

Record the colors found in each of the felt tip pens in a data table.

Pens or Food Color	Colors
Red	
Blue	
Black	
Green	



What are the colors found in black pens? What are the colors found in green? What are the colors found in red? Locate an artist's color wheel. Relate this to the separation of colors you have found in the pens. This is the pigmentary system. What are the primary colors? What are the secondary colors?

Have the students look up the label of food products in their kitchen cabinets to see how many items contain food coloring. Have them look especially at the label on beets, mustard, blueberry pie mix, and catsup.

You have separated a mixture of colors into the individual components by using the process call chromatography. This is a regular analytical procedure used by chemists.

APPLICATIONS AND IMPLEMENTATION OF ATOMIC STRUCTURE CONCEPTS

Since our understanding of basic chemistry is based on the atomic theory, students should become familiar with the composition of matter. Have them identify the "finger prints" of elements using diffraction grating and then relate this to spectral analysis of elements currently used by chemists. Introduce them to the way astronomers use this same principle to identify the elements present in space. Next, go one step further by relating this to the red shift theory of stellar motion. All of these are based on the use of the spectral lines to identify elements.

It is important that all students become familiar with the elements, compounds, and mixtures found in their surroundings. An in-depth study into the manufacture of cold cream, hand lotions, face creams, and lipstick can become an interesting activity, especially for girls.

UNIT VI
CHEMICAL REACTIONS

OBJECTIVE

The students will demonstrate the ability to recognize chemical reactions and apply these processes to the chemistry found in the home, building construction, and food processing.

TEACHING STRATEGIES

When a chemical change occurs, old substances are changed into new substances. There are a number of evidences of these changes such as light, heat, color, and new products. Gas is often evolved which is easily recognized. Give the students an opportunity to observe bubbles of gas being formed by having them do the activity EVIDENCE OF A CHEMICAL REACTION. It is important for the students to see changes that occur which cannot be easily reversed. RECOGNIZING CHEMICAL REACTIONS will give the students experience in recognizing the evidence of chemical changes.

Four different types of reactions can occur: composition, decomposition, replacement, and ionic. When two elements combine, this is a composition reaction. If a compound breaks down into two elements, it is called decomposition. When one element changes places with another element in a compound, it is called a replacement reaction. An ionic reaction occurs when elements recombine to form other substances. You might say the elements change partners. As the students do these activities, it is important for them to recognize evidences of changes and to understand the simple mechanism of most chemical reactions.

An example of the simplest type of reaction where two elements, iron and oxygen, combine to form one compound is in the activity IS OXYGEN USED IN THE BURNING PROCESS? Two activities involve a replacement reaction. These are CAN YOU TURN COPPER INTO SILVER? and CAN YOU COPPERPLATE A NAIL?

THE CHEMISTRY OF PHOTOGRAPHY and GRANNY'S OLD-FASHIONED SOAP are ionic reactions where atoms recombine to form new substances. In the other activities, the chemical changes are not quite so simple, as several reactions occur. These activities are CAN YOU MAKE A MONSTER?, MAKING A SYNTHETIC FOOD FLAVORING, and ALL AMERICAN RED, WHITE, AND BLUE EXPERIMENT. Be sure to point out the evidence of a chemical reaction such as heat, light, color change, or new and distinct products. As each activity is completed, review the evidences of chemical change and the type of reaction.

ACTIVITIES

- **Evidence of a Chemical Reaction**

Before anyone can determine if a chemical reaction has occurred, there must be some evidence of a reaction. Carefully drop a piece of mossy zinc into dilute sulfuric acid. Let it stand for a few minutes. What evidence is there of a chemical reaction? (A gas evolves) What is the gas that you see? (Hydrogen) Could you collect this gas and how? (Yes, collect the gas by the water displacement method. This is done by inverting a test tube full of water over the zinc.) Write the word equation for this reaction.

Zinc + Sulfuric Acid ➡ Hydrogen $_{(gas)}$ + Zinc sulfate

- **Recognizing Chemical Reactions**

This activity will aid the students in observing and recognizing the evidences of chemical reactions. These are recognized by the presence of one or more of the following during the formation of new substances:

1. Formation of a gas (bubbles observed)
2. Formation of a precipitate (solid generally settling to the bottom)
3. Distinct color changes (not simply an intensity change due to dilution)
4. Temperature increase or decrease

Prior to class, prepare the following chemicals. Place the liquids in dropping bottles and the solids in reagent bottles. Label each with numbers as follows:

Number	Chemicals
#1	Acetic Acid, .5M $HC_2H_3O_2$
#2	Sodium bicarbonate powder, $NaHCO_3(s)$
#3	Lead II nitrate, .5 M $Pb(NO_3)_2$
#4	Sodium chloride, .5 M NaCl
#5	Sodium hydroxide, 5.0 M NaOH
#6	Hydrochloric Acid, 6.0 M HCl
#7	Potassium chromate, .5 M K_2CrO_4
#8	Zinc Powder
#9	Potassium iodide, .5M KI
#10	Barium hydroxide powder, $Ba(OH)_2(s)$
#11	Ammonium thiocyanide powder, $NH_4SCN(s)$

Have the students transfer small quantities of each of the reactants to test tubes according to the data table. Careful observations must be made for each reaction. This will include checking for temperature change by touching the bottom of the test tube to the inside of the wrist for a short period following the mixing of the chemicals.

An important part of this exercise is the completion of the Data Table. Make certain that the students enter responses to each column as the experiment progresses. A sample entry is provided for the combination of chemicals 1 and 2. The data table should be reviewed to see if students are developing cognitive skills necessary for understanding chemical reactions.

DATA TABLE

RECOGNIZING CHEMICAL REACTIONS

Combinations	Observations		Chemical Reactions	
	Before Mixing	After Mixing	Yes/No	Why? (One of 4 clues)
1 & 2	#1 Clear liquid with odor like vinegar #2 White fine powder	Vigorous bubbling observed & slight temperature drop.	Yes	Gas produced & temperature decreased.
3 & 4				
5 & 6				
6 & 7				
5 & 7				
6 & 8				
3 & 9				
10 & 11				
6 & 10				
5 & 10				
2 & 6				

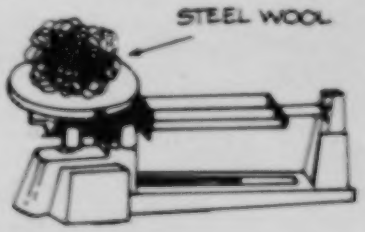
• Is Oxygen Used in the Burning Process?

Before a substance will burn, three basic items are needed: heat, fuel, and oxygen. For anything to burn it needs to be brought up to its kindling temperature. Along with this there needs to be a fuel, or something to burn. Then there needs to be oxygen which is usually taken from the air.

For this activity, you'll need steel wool, a balance pan, a piece of asbestos, and a match. Use a piece of steel wool about the size of a golf ball. Pull it apart so that plenty of air can get to the inside. Record the mass of the steel wool on the chalkboard. Place the steel wool on a piece of asbestos and light it with a match. Ask the students, how was the heat applied, what was the fuel, and where did the oxygen come from? After it has burned, determine the mass. What is the mass now? Why does it weigh more? What has happened? (The steel wool is now iron oxide as it has combined with the oxygen in the air.) What type of reaction is this? (composition) What evidence was there of a chemical reaction? (light)

Iron + Oxygen ➡ Iron oxide

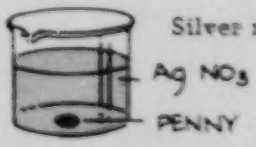
This is an example of a composition reaction where oxygen is taken from the air to combine with iron to form a compound.



• Can You Turn Copper into Silver?

The earliest form of chemistry was called alchemy where they tried to turn lead and iron into gold or silver. Their major contribution was to improve the methods of taking metals from ores. They also learned to use acids, designed balances for weighing chemicals, and made crucibles for melting metals.

In this activity you will need a shiny new copper penny, silver nitrate, and a beaker. Dissolve a few grams of silver nitrate in 100 ml of water. Drop the penny into the beaker. Leave it a couple of days. What is in the bottom of the beaker? (Silver) It is in a powder form now. How can you put this into a small pellet? (Filter the precipitate and place the silver in a crucible. Apply heat.) What is left in the solution? (Copper nitrate) What evidence is there of a chemical change? (A precipitate is formed.) What type of reaction is this? (Replacement) Write the word equation for this reaction.

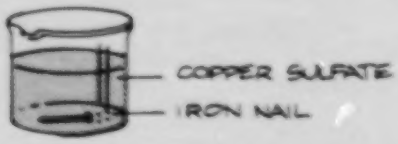


Silver nitrate + Copper ➡ Copper nitrate + Silver

• Can You Copperplate a Nail?

Dissolve about 5 grams of copper sulfate in 200 ml of water. Drop an iron nail in the solution. Let it sit for a day. What has happened to the nail? (It should be coated with copper) How does the nail look? Can you scrape off the copper with your fingernail? What type of reaction is this? (Single replacement reaction where the copper ions were replaced by the iron.) What evidence did you see of a chemical change? (A copper coated nail with the solution turning bluish.)

Copper sulfate + Iron ➡ Iron sulfate + Copper

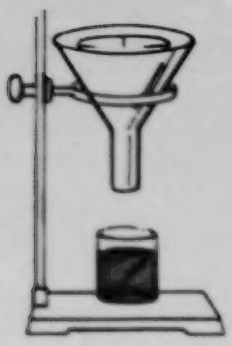


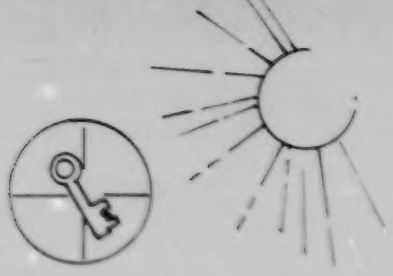
• The Chemistry of Photography

Sunlight decomposes silver compounds by producing a black residue. Photographic film or printing paper has been coated with silver bromide. When this is exposed to light, a chemical reaction occurs. Later the film or printing paper is placed in a solution called the developer which continues the action started by the light. When the picture is clear on the film or printing paper and is high lighted with dark objects, the film or print is placed in a solution to stop the reaction. This solution is called the fixer or hypo. This is where the leftover silver bromide on the film is dissolved leaving the silver deposit on the film or paper fixed with an image of the picture.

The first step of this process can easily be done in a classroom. Mix a solution of 17 grams of silver nitrate in 1 liter of water. The students can pour 20 ml in a test tube. To this add 20 ml of a sodium chloride solution. A white precipitate will form. Have the students filter this solution. As soon as they have filtered the solution, have them open the filter paper and place it flat on a paper towel. Next, place a key or coin on the filter paper and place it in the window where sunlight will strike it. What happened to the residue on the filter paper? (It turned dark) Is there evidence of a chemical reaction? (First a white precipitate is formed and then the sunlight turned the residue dark.) This is an ionic reaction where the negative and positive ions change places. Write the word equation for this reaction.

Silver nitrate + Sodium chloride ➡ Silver chloride + Sodium nitrate





This is the first step in the photographic process. Many other chemicals have been tried but silver still makes the best photographic film and paper. What happens to the silver that is washed down the drain in the fixer? (Most large commercial labs save these chemicals and reclaim the silver.)

- **Granny's Old-Fashioned Soap**

Maybe some of the students will have grandparents who can remember making soap. This was a very common practice in South Carolina, as the raw materials were readily available. The fat or oil was usually the lard from a hog. After a hog was dressed, the fat was heated and boiled down into lard and saved for cooking and soap making. They soaked the wood ashes in water to get potash.

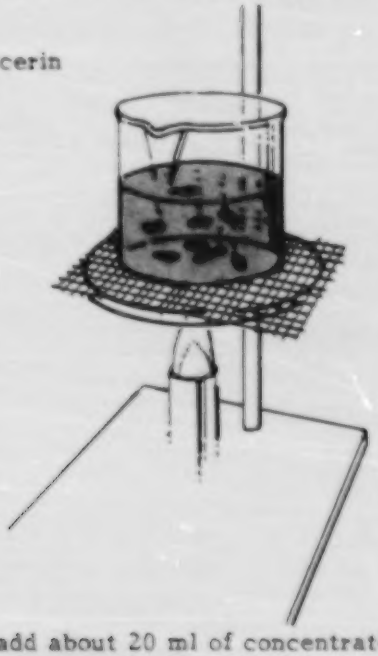
Granny put the lard and potash in a big iron pot in the yard and built a fire under it. Next she boiled the lard and potash together until the soap was formed by a chemical reaction. The by-product was glycerin which now has many other uses such as cosmetics, drugs, and explosives. Sodium chloride or common table salt aided in the separation of the soap and glycerin. Usually each community had its own source of salt from a mine. Therefore, all of the raw products were readily available without purchasing. After the soap was made, it was poured into wooden molds and stored for later use.

The students can make their own soap by using bacon drippings (lard, cottonseed oil, or any other fat), sodium hydroxide, and salt. Before the students begin this activity, make certain that they are wearing safety glasses as spattering can cause serious eye damage. Place about 10 ml of bacon drippings in a beaker. Add to this a solution of 3 grams of sodium hydroxide dissolved in 5 ml of water. Gently heat for about 30 minutes. Allow to cool and add a solution of 5 grams of salt dissolved in about 15 ml of water. Try to mold the soap into cakes. Allow to dry for a day and have the students wash their hands with Granny's Old Fashioned Soap.

How did you know a chemical reaction had occured? (New substances were formed) What is the difference in this soap and what you buy at the store today? (Color and perfume have been added to the store bought soap.) Which soaps on the market closely resemble Granny's soap? (Octagon or lye soap) Why is it called lye soap? (Lye soap is made with sodium hydroxide, lye.) What are the uses of glycerin? (Cosmetics, drugs, and explosives) What is the difference between a detergent and a soap? (Soap is a detergent. The products we call detergents have an entirely different chemical composition.) How is soap manufactured commercially? (The fats are refined with perfume and dyes added.) What is the cleaning action of soap? (The soap molecule has an oil soluble end and a water soluble end. The oil soluble end tends to dissolve the oily end of the dirt molecule, while the water soluble end dissolves in the water.)

Write the word equation for the chemical reaction of making soap on the chalkboard.

Fat + Sodium hydroxide ⟶ Soap + Glycerin



- **Can You Make a Monster?**

To a 100 ml pyrex beaker half filled with sugar add about 20 ml of concentrated sulfuric acid. Wait a few minutes. What happened to the sugar? Was there evidence of heat? (Yes) Some chemical reactions need heat for activation while others give off heat. When a reaction gives off heat it is called an exothermic reaction. What is the residue? (Carbon) What is the word equation for this decomposition reaction?

Sucrose (table sugar) $\xrightarrow{\text{Sulfuric Acid}}$ Carbon + Water

$$2C_6H_{12}O_{11} \xrightarrow{H_2SO_4} 12C + 11H_2O$$

What is the gas given off? (Water in the form of steam.) What is the purpose of the sulfuric acid? (Catalyst) What is the evidence of a chemical reaction? (New substances and heat) The residue can be likened to a monster as it rises above the beaker.

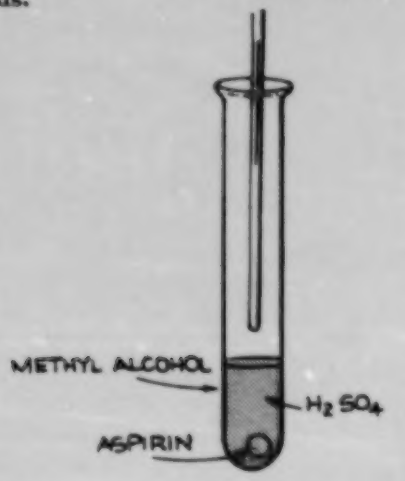
- **Making a Synthetic Food Flavoring**

Many artificial food flavorings have been developed that we eat daily. Just read the labels on the products that you eat. One that can be made in class is wintergreen. You'll need methyl alcohol, sulfuric acid, and an aspirin plus a test tube. This activity is best done in groups of 2 or 3 students.

Place 15 ml of methyl alcohol in a test tube. Add 5 ml of diluted sulfuric acid. Stir with a stirring rod for a few minutes. Then add a crushed aspirin tablet and stir a little more. Stopper the test tube with a piece of cotton. Allow this to stand about 15 minutes. Remove the cotton and have the students waft the test tube. What is the odor? Where have you smelled this before? What evidence was there of a chemical reaction? (Wintergreen was formed) What is the word equation for this reaction?

Methyl alcohol + Acid (Aspirin) $\xrightarrow{\text{Sulfuric Acid}}$ Wintergreen + Water

What is the purpose of the sulfuric acid? (Catalyst) Many artificial flavorings such as banana, juicy fruit, and pineapple are made from a combination of alcohols and organic acids.



• **All American Red, White, & Blue Experiment**

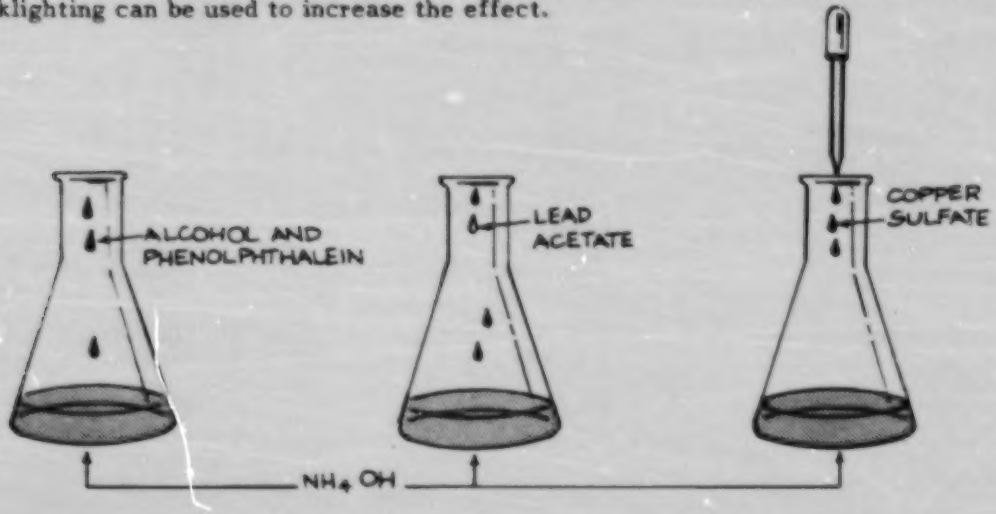
You'll need a dilute solution of about 250 ml of ammonium hydroxide in three separate flasks. A different solution will be added to each of these flasks.

To the first flask add 5-10 drops of alcohol solution containing 3-4 drops of phenolphthalein solution.

To the second flask add 5-10 drops of concentrated lead nitrate solution.

To the third flask add 5-10 drops of concentrated copper sulfate solution.

The number of drops can be adjusted in order to obtain a greater color intensity. Backlighting can be used to increase the effect.



What are the colors of the solutions? (Red, white, and blue) What are the reactions in each of the flasks? (In the first flask, the ammonium hydroxide reacted with the indicator. In the second flask, lead hydroxide was precipitated. In the third flask, a blue complex ion was formed with copper and ammonium ions.)

Ammonia hydroxide + Lead nitrate ⟶ Lead hydroxide + Ammonia nitrate

APPLICATIONS AND IMPLEMENTATION OF CHEMICAL REACTIONS

The advances in American industry have been based on chemistry. Products such as soaps, detergents and the manufacture of cement and fertilizer have grown from very simple chemical reactions into complex reactions that increases production and makes the product more attractive to the buyer. After the students make the soap, have them find out how the process of soap making has been refined before the final product gets to their soap dish or washing machine.

The processes involved in making cement have become very complex beginning with the mining of raw materials such as limestone and clay. Even though these raw materials are low in cost, the machinery, fuel, and power necessary for production are very expensive. This process should be investigated by the students.

The importance of fertilizers is another interesting application of chemical reactions to investigate. Three major elements nitrogen, phosphorus, and potassium are needed for plants. Cattle and poultry must eat the nitrogen in plants in order to make protein. Therefore, large quantities are needed to fertilize forage crops. Phosphorus is necessary for release of energy during digestion. Potassium regulates the water fluids in the body. As crops are grown, all three elements need to be replenished annually in the form of fertilizer. Have the students investigate the compounds and the chemical reactions involved when fertilizers are added to the soil.

UNIT VII
ACIDS, BASES, AND SALTS

OBJECTIVE

The students will demonstrate the ability to distinguish between the properties of acids and bases and relate these to salt formation in the neutralization process by using indicators.

TEACHING STRATEGIES

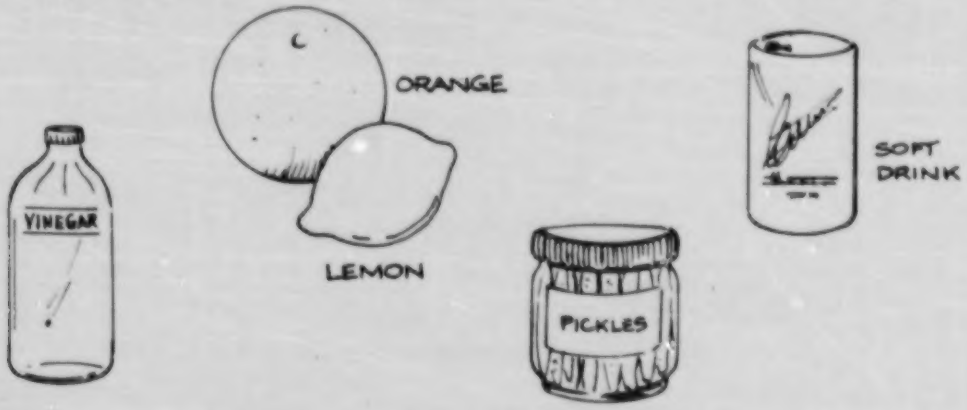
A variety of demonstrations and hands-on activities can be used to illustrate the properties of acids and bases. Begin by collecting a number of acids and bases found around the house as explained in the activities ACIDS IN MY HOUSE! and WHAT'S SO BASIC ABOUT BASES? Another interesting activity illustrating how acids and bases conduct electricity is CONDUCTIVITY OF ACIDS. Acid-base indicators offer a visual difference between acids and bases by observing color variations as materials go through transition changes. By making RED CABBAGE JUICE INDICATOR, the students will grasp a better understanding of the use of indicators and pH scales used to determine strengths of acids and bases.

A very simple activity but one that can be experienced daily will be found in IS TEA AN INDICATOR? This is where tea becomes an indicator in the presence of lemon juice, the acid. Two activities are on neutralization where an acid and base produce a salt. NEUTRALIZATION PRODUCES A SALT! and ARE ANTACIDS NEUTRALIZERS? will demonstrate the process involved when a salt is formed and how antacids react in the stomach to counteract acid indigestion.

ACTIVITIES

- **Acids in My House!**

Have the students bring in all the acids found around the house such as vinegar (Acetic acid), oranges, lemons, grapefruit (All citrus fruit contains citric acid), apples (Malic acid), tomatoes, pickles, tea, and carbonated drinks. Other items that can be brought in are milk that is souring (Lactic acid) and rancid butter (Butyric acid). Test each of these acids with pH paper or universal indicator. Sequence these according to strengths. Select one or two students to taste these acids. Are all of these acids sour? These are all familiar acids commonly found around the house that are considered to be weak acids.



The strong or industrial acids are sulfuric, hydrochloric, and nitric acids. These are caustic acids and cannot be tasted, but these can be tested with pH paper and universal indicator. Where is sulfuric acid found around your house? (In the automobile storage battery) Your body is constantly making hydrochloric acid. How is this acid used in your body? (The gastic juices are primarily hydrochloric acid.) An impure form of hydrochloric acid is used to clean mortar from stone and brick. This is called muriatic acid. Nitric acid is not ordinarily found around the house as it is used in purifying metals and making fertilizer and explosives. All three of these acids, sulfuric, hydrochloric, and nitric, are called industrial acids. Why are these acids called industrial acids? (Because these acids are used in large quantities by industries) Why are these acids called caustic acids? (Because these acids corrode metals)

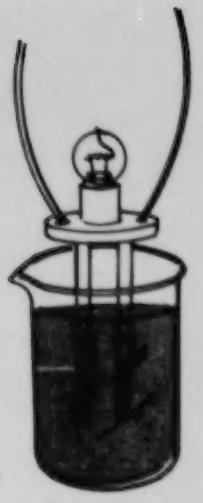
- **What's So Basic About Bases?**

What are the bases commonly found around the house? Have the students bring in soap, shampoo, ammonia, milk of magnesia, window cleaner, and lye. Have them feel the shampoo and soap. Are these slippery? Make a very weak solution of ammonia so that the students can feel its slippery properties. Test the bases with pH paper. Line them up in order of strength. Other indicators such as pH paper, universal indicator, litmus paper, and phenolphthalein can be used to test the bases. Phenolphthalein reacts in the human body as a laxative. Verify this by looking on the label of Phenolax and ExLax. If litmus is used as an indicator, remember the saying "Blue, Base, Bitter." Bases turn litmus paper blue and taste bitter.

Compare the household bases to the strong bases such as sodium hyroxide and potassium hydroxide by testing these bases with indicators. Do not have the students taste or feel these strong bases.

- **Conductivity of Acids**

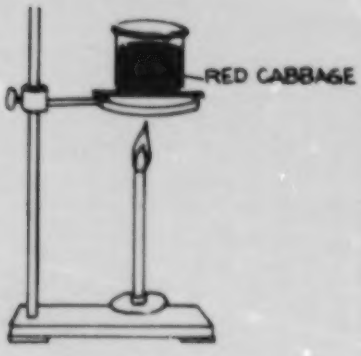
The property of acids to conduct electricity can be illustrated with a very simple piece of equipment called the conductivity apparatus. Set up the apparatus using tap water. Then add a drop of sulfuric acid at a time until the bulb lights up. In order for the students to see that all chemicals do not conduct electricity, test isopropyl alcohol in the same way that you did sulfuric acid. Remember the electrodes must be cleaned after each test.

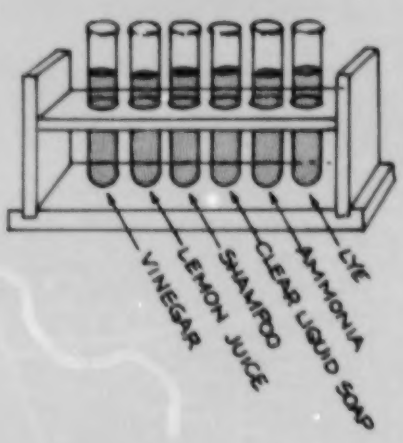


- **Red Cabbage Juice Indicator**

Indicators turn different colors in acidic and basic solutions. There are a variety of indicators on the market. Several are used for general testing such as universal indicator, pH paper, and phenophthalein. One that can be made in the classroom is red cabbage indicator. Boil a few red cabbage leaves in water for about 10 minutes. This juice is an indicator as it turns a variety of colors when it comes in contact with white vinegar, lemon juice, shampoo, liquid soap, weak solution of lye, ammonia, and clear carbonated drinks. Making red cabbage indicator and then testing all the household acids and bases is an excellent activity for students.

Next, have the students arrange these in order of strengths of acids and bases. Assign pH numbers to each of the colors starting with the reds in the lower pH numbers of 1 or 2 and going to the purplish colors with a pH of 8 or 9.





- **Is Tea an Indicator?**

Have you ever noticed how tea changes color when lemon juice is added? Try adding a small amount of lemon juice to a strong glass of tea. What happened to the color of tea? Which is the indicator the lemon or the tea? (The lemon juice is the acid and tea becomes an indicator.)

• **Neutralization Produces a Salt!**

In the process called neutralization, an acid and base combine to form salt and water. You can prepare table salt, sodium chloride, by combining dilute hydrochloric acid with dilute sodium hydroxide. Use phenolphthalein as an indicator to determine when the solution is neutral. Phenolphthalein in the presence of an acid is colorless and pink in the presence of a base. When your solution is neutral, a few drops of hydrochloric acid will cause the solution to be colorless while a few drops of sodium hydroxide will make the solution turn pink. Next evaporate the solution. What is the shape of the crystals? Allow the students to look at these crystals with a magnifying lens. Does the residue taste salty? The reaction between an acid and a base forms a salt. The process is called neutralization. In this case sodium chloride, table salt, and water are formed. Many other salts are formed in this same way with a combination of acids and bases. Remember on the pH scale, the position between an acid and a base is neutral. In the process called neutralization, an acid and base combine to form salt and water.

$$\underset{\text{Acid}}{HCl} + \underset{\text{Base}}{NaOH} \longrightarrow \underset{\text{Salt}}{NaCl} + \underset{\text{Water}}{H_2O}$$

- **Are Antacids Neutralizers?**

The action of an antacid can be demonstrated by using prepared gastric juices and any of the commercial antacid products found on the market. Pour a few milliliters of gastric juices in a beaker or make a slightly acid solution with dilute hydrochloric acid. Use a drop or two of universal indicator. Notice the color. Then drop an antacid tablet in a beaker. After the reaction, what color is the solution in the beaker? Why do we call these "antacids"? What is this reaction called? (Neutralization) How does an antacid tablet counteract acid indigestion? (Neutralization of the acid occurs.) Try as many of the antacids as possible.

APPLICATIONS AND IMPLEMENTATION OF ACID, BASE, AND SALT CONCEPTS

Household chemistry is not complete without an understanding of the differences between acids and bases, use of indicators in establishing a pH scale, and the process of neutralization. The use of fertilizers is one of the best applications of acids, bases, and salts. Lime is used by farmers to neutralize the soil when the acidity becomes too high. Soil is tested for acidity using the pH scale. Have the students find out how pH tests are made by the Clemson Extension Service and what chemicals are used to neutralize the soil. Then test the soil on the school grounds where the shrubbery is grown. Certain plants such as the hydrangea have different colored flowers depending on the pH of the soil. Find out the pH of the soil that is necessary for growing corn, cotton, tobacco, and soybeans. How are fertilizers manufactured?

Another application of this study of acids and bases is the problem with acid rain. Certain chemicals from industries combine in the air to form acids. The students will be able to find numerous articles in newspapers and magazines on causes of acid rain as well as prevention of harmful effects.

UNIT VIII
TEMPERATURE AND HEAT

OBJECTIVE

The students will analyze the properties of heat and determine how man has learned to measure it.

TEACHING STRATEGIES

The major source of heat is the sun. Man has learned to produce heat through chemical changes by burning, friction, electrical resisitance, and nuclear reactions. Before students learn how heat is used, they must first learn how it is measured. The devices used to measure temperature are based on the principle that most substances expand when heated and contract when cooled. Keep in mind that water is unique, it expands when it freezes. The activities DO LIQUIDS EXPAND WHEN HEATED?, DO GASES EXPAND WHEN HEATED?, and DO SOLIDS EXPAND WHEN HEATED? will give the students experiences that will lead to a better understanding of how the principle of expansion and contraction of solids, liquids, and gases is used to measure the temperature of different materials. Be sure to relate these activities to practical applications.

ACTIVITIES

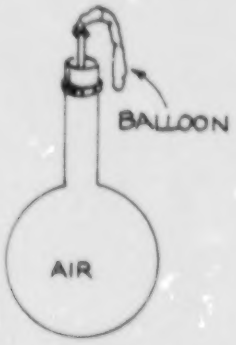
- **Do Liquids Expand When Heated?**

In order to make a colored water thermometer, you will need a florence flask, a one hole rubber stopper, 20-30 centimeters of glass tubing, and several drops of food coloring in water. Assemble the apparatus according to the illustration. Fill the flask with water. Make certain that there is enough water and food coloring in the flask so that there is water in the glass tubing. Now gently heat the flask. What happened to the level of the liquid? (The level of the water should rise in the glass tubing.)

This water thermometer is based on the principle that liquids expand when heated and contract when cooled. What would happen to the thermometer you just made if the temperature were to go below freezing? (As water freezes it expands, therefore the water would expand and break the flask.) Could you use a colored water thermometer outdoors in the winter time in South Carolina? (No) What are the liquids used in the laboratory thermometers? (Some are filled with red alcohol and others with mercury.) Find out the freezing temperature of each of these liquids. What is the difference in price? What kind of thermometers are usually found in houses?

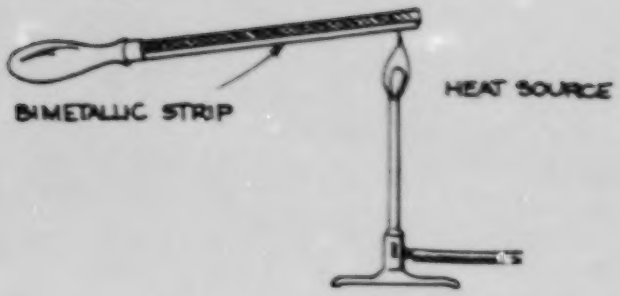
- **Do Gases Expand When Heated?**

In the last activity you saw how liquids expand when heated. Now let's see if gases expand when heated. Assemble a flask, one hole rubber stopper, 2-3 centimeters of glass tubing, and a balloon as seen in the illustration. Gently heat the flask. What happened to the balloon? On a hot summer day, does the air in an automobile tire expand? (Yes)



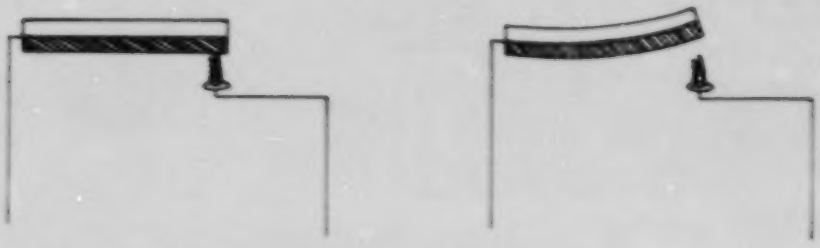
- **Do Solids Expand When Heated?**

A bimetallic strip will be needed to demonstrate this activity. Most of the bimetallic strips or compound bars are made by laminating strips of iron and brass. Gently apply heat to the bimetallic strip. What happened? (The brass expands faster than the iron causing the bar to bend.) The compound bar is based on the principle that metals expand at different rates. Each metal has a different coefficient of linear expansion that is characteristic of that particular material. As each metal expands a different amount, the bimetallic strip bends as it is heated. The more heat that is applied, the greater the expansion as well as the bending of the metals.



Could this be used to measure the temperature of substances? (Yes) How is a bimetallic strip used in a thermostat? (In a thermostat used to control the amount of heat in a room, the bimetallic strip touches the contact point turning on the heat. As the air is warmed, the bimetallic bar is bent away from the contact point, cutting off the electricity to the heater.) Obtain an old thermostat from a heating and refrigeration company. Get an old car thermostat from a mechanic. Demonstrate how each of these works. Get a thermostat used to control the air-conditioning unit in a house. Show how this one is different than the one used to control heat.

It is important to understand the function of a bimetallic strip in a thermostat. Have the students trace the current in a diagram of a thermostat used for both heating and air-conditioning systems.



THERMOSTAT IN A HEATER

APPLICATIONS AND IMPLEMENTATIONS OF DEVICES USED TO MEASURE HEAT

Temperature is measured by instruments that are based on the tendency of materials to expand when heated and contract when cooled. Liquid thermometers are checked daily by most people either through the news media or by observations. A variety of thermometers should be available for classroom use such as a mercury, red alcohol, and clinical. There are several reasons for the little crook in the vein of clinical mercury thermometer. What are the purposes for this crook? (This crook allows the mercury to stay at one place so it can be easily read. It also produces "differential thermometry" where the full span of the short clinical thermometer is just a few degrees. Otherwise, the clinical thermometers would be as long as a laboratory thermometer.) Why does the clinical thermometer have to be "shaken down" after each use? (The mercury will not go down in a clinical thermometer unless it is forced to go down by shaking. In a laboratory thermometer the mercury goes up and down depending upon the surrounding temperature. This is why you never shake down a laboratory thermometer.)

How is the temperature taken of babies, cows, cats, and dogs? (Usually a rectal thermometer is used.) Find out the normal temperature for each of these animals. Investigate the thermometers used to take the temperature of patients at the hospitals? What is the temperature considered normal for humans? (98.6 degrees)

The principle that gases expand when heated and contract when cooled can be applied to large air masses. What happens to the density of air when it is heated? (Hot air expands causing the density to go down.) Is hot air heavier or lighter than cool air? (Hot air is lighter than cold air.) Relate this to air masses colliding causing different types of weather fronts. Now apply this to confined masses of air in a balloon. Explain why hot air balloons rise.

The use of a bimetallic strip in measuring the temperature of rooms can be correlated to expansion joints in bridges or concrete sections in highways. How about the fillings in your teeth? Does the expansion rate of the fillings have to be matched to that of your teeth? (Yes) Why does the copper bottom of a Revere Ware pot keep from separating from the stainless steel when heated? (Compare the expansion rate of copper to stainless steel.)

Be sure to point out that water is unique. It does not follow this same pattern. As water approaches zero degrees centigrade, it begins to expand. Crystal formation of water takes up more space than water in the liquid state. Why do pipes break during a cold spell in the winter? (Water expands when it freezes.) Why do ice cubes float? (The density of ice is less than that of water.) Why is ice always on the surface of a pond? What is the purpose of antifreeze? (It lowers the freezing point of the mixture.) What is antifreeze? (Ethylene glycol)

UNIT IX
RADIOACTIVITY

OBJECTIVE:

The students will be able to compare the properties of radioactive particles, their decay rates, and determine ways to handle nuclear waste disposal.

TEACHING STRATEGIES:

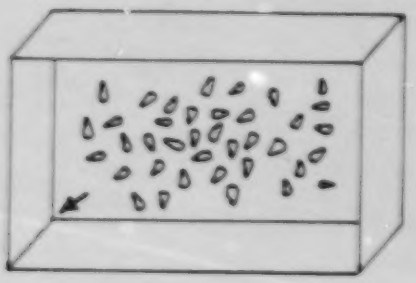
Simulation activities can be easily used to teach radioactive concepts. The properties associated with radioactivity are unique and are not readily understood unless the students are able to learn through concrete experiences. A problem associated with studying radioactivity is the use of hands-on activities by handling of radioactive isotopes. This can be dangerous and unnecessary at this stage of learning. Simulation activities can be used to illustrate the principles making this type of a lesson safe yet very beneficial.

By using a simulation activity called WHAT'S HALF-LIFE ALL ABOUT?, students will be able to relate the decay rate of radioactive isotopes to a probability game. Chain reactions can be related to the domino theory in the activity WHAT'S SO IMPORTANT ABOUT THE DOMINO THEORY? THE BUTTER GUN LAW! is an excellent way to explain the inverse square law. This law applies to the decay rate of radioactive elements as well as the strengths of gravitational forces compared to the distances and the dispersion in space of sound and light.

A geiger counter is essential for demonstating RADIOACTIVE DETECTING and SHIELDING, as it will give the students first hand experiences in how radioactivity is detected and how man has learned to use shielding as a way of protection from radioactive particles.

- **What's Half-Life All About?**

This is a simulation activity that demonstrates half-life properties of radioactive isotopes. A bag of corn seed will be needed and at least 6-8 boxes about 8 ½" x 11" x 2". Make a directional arrow in a corner of each box, then place 100 kernels of corn in each box. Divide the students into groups of four or five so that each group has a box and have one student out of each group shake the box. Next have the students carefully remove each of the kernels that are pointed in the same direction as the arrow. Record the number in the data table. Shake the box again and remove the kernels pointed in the direction of the arrow. Repeat this until there are only about 10-15 kernels of corn left.

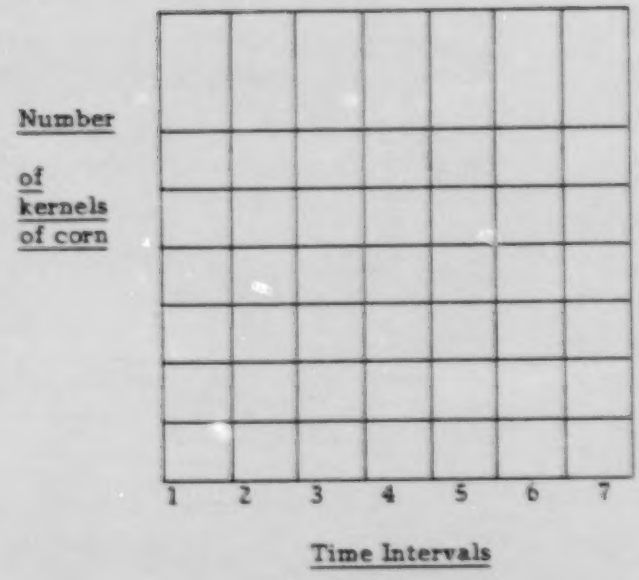


SUGGESTED DATA TABLE

Half-life Data Table

Trial	Number of Kernels Removed
1	
2	
3	
4	
5	
6	
7	

Graph of Half-life



This activity demonstrates the half-life properties of radioactive isotopes. It is a simulation type activity that will aid the students in understanding the way a radioactive isotope undergoes decay. The time for each radioactive isotope to decay is not illustrated in this activity; therefore, a comparison should be made of the decay rate of several isotopes such as U-238, C-14, and P-32.

- **What's So Important About the Domino Theory?**

This activity will provide the simulation of a chain reaction that occurs during nuclear fission. Dominoes are used to demonstrate this principle. Arrange the dominoes in an upright position and close enough so that when you push over one of them all the others will in turn fall over. Draw the analogy of a chain reaction that occurs in fission to the domino theory where one reaction leads to another and so on just like the dominoes falling over. The atomic bomb is a good example of nuclear fission where a chain reaction occured.

• The Butter Gun Law!

Some principles that entail mathematics are a little easier to understand if an analogy is used. In this case, the formula for the inverse square law will be explained by relating a story about a restaurant owner who was trying to beat inflation. The formula is as follows:

$$\text{Intensity} = \frac{1}{\text{Radius}^2}$$

The inverse square law principle can easily be related to every day experiences. Let's call it the tale of the "Butter Gun Law."

Restaurants have a way of evenly spreading butter on bread by using a butter gun. When a piece of bread is placed fairly close to the gun, one squirt covers the bread. With inflation, the restaurant owner wanted to cut costs by making the butter last longer. He placed the bread farther away from the butter gun. By doing this he could cover 4 pieces of bread with the same amount of butter. All went well with the business until he realized that inflation had set in a little bit more. He reasoned that if he placed the bread farther away from the butter gun, he would be able to cover 9 pieces of bread. He was very pleased with this cost saver, but in a very short time more inflation set in. Once again he placed the bread a little farther away from the butter gun. How many pieces of bread did he cover this time (16 pieces of bread).

As you relate the tale of "The Butter Gun Law," be sure to illustrate the diagram of the inverse square law on the chalkboard and substitute figures in the formula.

$$I = \frac{1}{\text{Distance}^2} \qquad I = \frac{1}{1^2}$$

$$I = \frac{1}{\text{Distance}^2} \qquad I = \frac{1}{2^2}$$

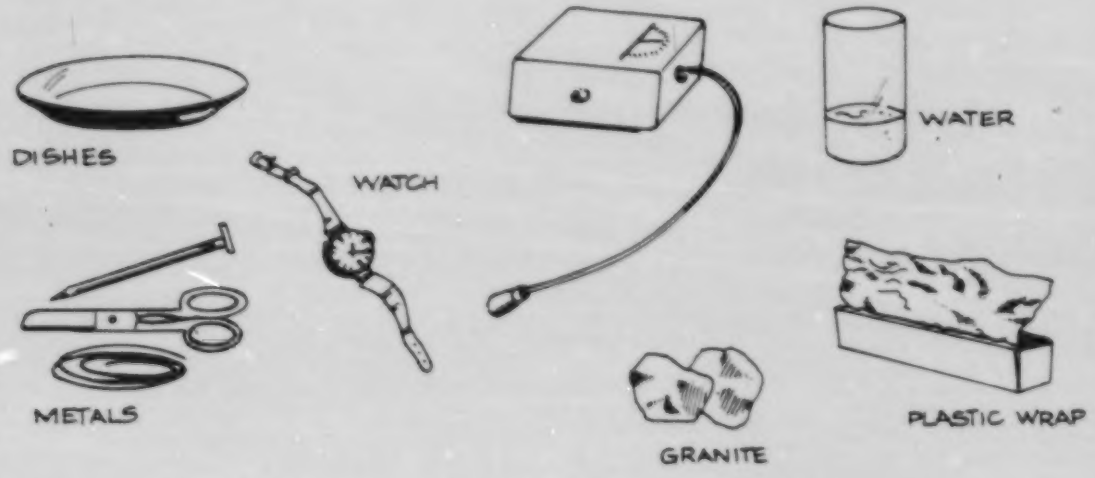
$$I = \frac{1}{\text{Distance}^2} \qquad I = \frac{1}{3^3}$$

By drawing the diagram of the inverse square law on the board and relating the tale of the "Butter Gun Law," the decline in intensity of the radiation can be easily understood. This can also be illustrated with a hair spray or window cleaner dispenser.

- **Radioactive Detecting**

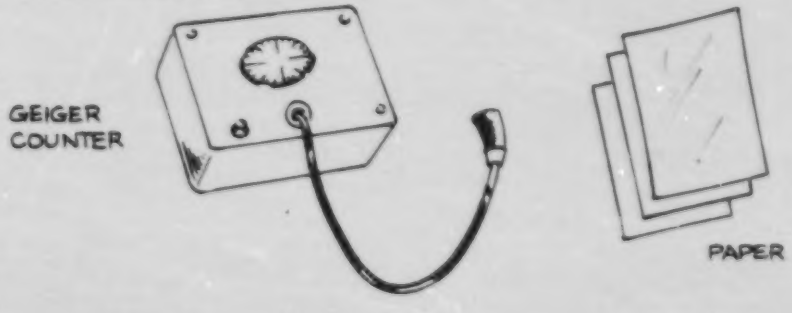
Geiger counters have been developed to detect radiation. A fairly inexpensive one can be obtained from a scientific company. There are several good activities to do with one of these sets. If possible get one with head phones so the students will be able to hear the sporadic disintegration of the nuclei.

Many materials in our surroundings are radioactive. Find out which ones are radioactive by testing everything imaginable with a geiger counter probe. Try granite, old watches or clocks, dishes, bricks, plastic wrap, metal of all kinds, and a variety of foods. Even try water! Granite has a small amount of natural radioactivity. Remember there is a certain amount of radioactivity naturally all around us. Find out what is meant by background count.



- **Shielding**

Use the test source on the side of the geiger counter box to determine which materials shield radioactivity. Try a few sheets of paper at a time. Next, use cardboard or construction paper for shielding beginning with a few sheets at a time until you have used a number of sheets. Try different amounts of aluminum foil. Next, try lead sheets. Which is the best shielder? (Lead) When radioactive material is transported across the United States, which material would be the best to use for shielding? (Lead containers)



APPLICATIONS AND IMPLEMENTATIONS OF RADIOACTIVE PROPERTIES

By now the students should have a pretty good idea of the properties of radioactive materials. The half-life concept of radioactive decay should be made clear with the simulation activity. Chain reactions should be understood through the domino theory. THE BUTTER GUN LAW! will help the students to realize how the inverse square law applies to dissipation of radiation. The geiger counter will give the students an opportunity to analyze which materials are radioactive and which are not. Then the principle of shielding can be demonstrated by using a variety of materials and thicknesses.

Once these concepts are understood, the problem of nuclear waste disposal can be considered. It is an issue in South Carolina and one that will be with us for a long time. Therefore, the students should find out about the methods used to dispose of nuclear waste. These are some of the questions for the students to answer:

What is the difference between low-level and high-level waste?

How is low-level radiation stored?

How is high-level radioactive waste disposed?

How is nuclear waste solidified?

Why are salt mines considered to be safe storage for nuclear wastes?

How is nuclear waste stored at the disposal plant in Barnwell, South Carolina?

Why is a significant proportion of the nuclear waste for the United States brought to South Carolina?

What is South Carolina doing to protect this state from being the dumping ground for nuclear waste?

UNIT X
MECHANICS

OBJECTIVE

The students will demonstrate the ability to relate the principles and laws associated with mechanics to daily occurrences.

TEACHING STRATEGIES

It has been a challenge of human endeavors for man to devise machines that make life easier. It has been through this challenge that many laws and principles pertaining to motion, work, power, and simple machines have been derived. Most of these laws are based on principles that can be easily demonstrated in a classroom. The students must be given an opportunity to participate in as many of these activities as possible and then relate these experiences to daily occurrences. At the end of each major concept, Applications and Implementations will relate these activities to real world experiences.

The students should understand the differences between location, speed, velocity, and acceleration. It is important that each student understand the most fundamental measurement of position or location. In the activity WHERE IS YOUR SCHOOL LOCATED?, each student will have an opportunity to determine the coordinate points of his own school. WHAT IS YOUR WALKING SPEED? should aid the student's understanding that speed is simply the distance divided by time. Often the term displacement is used instead of distance. When speed is given a direction, it becomes a velocity. Accelerated motion, on the other hand, is the concept that an object is going faster in the second interval of time than it went during the first time period. WHAT IS ACCELERATED MOTION? will give the students an opportunity to determine and then see the spacing between successive intervals of time during accelerated motion. The formula for accelerated motion, distance = ½ acceleration X time X time can be proven by GALILEO'S 17TH CENTURY EXPERIMENT. The two constants, ½ and acceleration, are eliminated and a proportion is used. Distance then becomes proportional to the time squared.

SHOOT THE METAL CAN! is a classic demonstration that helps students visualize how objects fall at the same rate regardless of their masses. Because of the student's interest in projectile motion, the activity DROP ONE SHOOT ONE! will also aid in their understanding. This activity illustrates in a dramatic way that vertical motion of falling objects is independent of horizontal motion. WHAT IS THE BEST ANGLE FOR THE LONGEST RANGE? can easily be demonstrated with running water in the classroom. This should be correlated with the angle that a cannon is aimed for maximum range.

A study of motion would not be complete unless students can see that air friction affects free fall motion. The COIN AND FEATHER EXPERIMENT! is an excellent way for students to depict the difference between free fall motion of an object in air compared to that in a vacuum. Another activity that illustrates the effect of air friction on falling objects can be demonstrated very simply with AIR FRICTION ON PAPER by dropping one crumpled piece of paper and one flat piece of paper.

$d \propto time^2$

The symbol $\propto$ means proportional to

It will take a combination of these activities to illustrate to the students the principles associated with motion. Review the concepts by relating these to everyday occurrences.

COKE BOTTLE INERTIA, INERTIA OF L'EGGS, EGG DROP, COMPARISON OF FORCES NEEDED TO STOP AN 18-WHEELER AND A COMPACT, CAN YOU DEMONSTRATE NEWTON'S THIRD LAW WITH A BALLOON?, WHEN ARE FORCES EQUAL?, DOES THE WALL EXERT A FORCE? and USE INDIAN WRESTLING TO EXPLAIN NEWTON'S THIRD LAW are activities that will help students understand Newton's Three Laws of Motion.

Two activities on momentum, CONSERVATION OF MOMENTUM and MOMENTUM CONSERVATION OF A TOY PENDULUM should give the students a better understanding of the concept of conservation. IS MOMENTUM EQUAL TO IMPULSE? will continue the conservation concept and include the concept that force applied over time is equal to momentum.

Center of gravity should be made very apparent by doing a number of these activities: WHERE IS THE CENTER OF SOUTH CAROLINA?, WHAT DOES THE CENTER OF GRAVITY HAVE TO DO WITH WHEEL BALANCING?, IS THE CENTER OF GRAVITY DIFFERENT FOR A MALE AND FEMALE?, CENTER OF GRAVITY AS IT AFFECTS STABILITY, and CENTER OF GRAVITY AND STABILITY. Once the term center of gravity is introduced, the use of the term center of mass can be introduced. This is really a better term to use especially when studying space science.

The best way to have the students understand work and power is for them to determine their own hp in WHAT IS YOUR HORSEPOWER? Because the history of the United States is so closely related to the development and use of machines, the students should be able to identify and explain each of the simple machines by doing the activity LOCATING SIX SIMPLE MACHINES. These machines are used daily to make work easier.

A lesson on machines would not be complete unless students can identify the main function of automobile parts through the activity, WHAT'S UNDER THE HOOD?

ACTIVITIES

- **Where Is Your School Located?**

The most fundamental measurement is position or location expressed in coordinate points. These points, longitude and latitude, for your school can be determined by using a South Carolina road map. Obtain a set of road maps called the South Carolina Map Primary Highway System from the SC Department of Highways and Public Transportation at no cost. Be sure to get one for every student in the class. Store these maps for use another year.

Relate to the past and present experiences of the students by having them locate several familiar places on the map such as Columbia, the capital of South Carolina, Myrtle Beach, Lake Marion, Lake Murray, Lake Moultrie, Savannah River, Charleston Harbor, Port Royal Sound, Francis Marion National Forest, Sumter National Forest, I-26, I-85, I-20, & I-77.

Now have them locate their school and determine the longitude and latitude for this location. Notice that the coordinate points are on the side of the map in very small print; also the grid for longitude and latitude are printed on the road maps with very fine lines. Make certain that the students see these lines. What are the coordinate points for your school? What are the coordinate points for Myrtle Beach? (Almost 79 degrees longitude and almost 34 degrees latitude) What are the coordinate points for Columbia? (81 degrees longitude and 34 degrees latitude) Ask the students to locate several other points of interest.

Illustrate with a globe the origin of this coordinate system that we use to locate positions of places in the world. Where is zero longitude? (Prime meridian is zero longitude) Where is this located? (On a line drawn from the North Pole through Greenwich, England, and on to the South Pole.) Longitude is also a measure of time and is divided into 24 time periods, one for each hour of the day. Where is the International Date Line located? (180 degrees from the prime meridian) Latitude refers to the location or distance north or south of the equator. What is the latitude of the Equator? (0 degrees) What is the latitude of the North Pole? (90 degrees)

Relate the coordinate points on a globe to the positions that you have just located on the highway map. What are the parameters of longitude and latitude for South Carolina? (Longitude is between 79 and 84 degrees. Latitude is between 32 and 36 degrees.)

- **What Is Your Walking Speed?**

To determine a student's walking or jogging speed, mark off 100 feet with your yard stick. Using a stop watch, determine the time it takes a student to jog or walk this distance. One of your students may be wearing a digital watch with a stop watch capability.

Use the formula:

$$\text{Speed} = \frac{\text{Distance (feet)}}{\text{Time (seconds)}}$$

This will give your student's walking or jogging speed in feet per second. It will be easier to measure the student's jogging speed in the classroom by measuring 10 feet. Have several students take turns measuring their walking speed for this 10 foot span. This should give the students an understanding of how rates or speeds are measured.

- **What Is Accelerated Motion?**

An aluminum pan, string (4 meters), and 5 large nuts will be needed to demonstrate accelerated motion. The nuts will be tied onto the string at intervals associated with the distance a freely falling object falls each interval of time.

This activity will be demonstrated by standing on a chair and dropping the nuts and string in such a way that you hit the aluminum pie pan. The students will hear the sound as each nut hits the aluminum pie pan. The obvious observation of the spacing between the nuts and the sound that is heard will give the students a concrete visual as well as auditory way of understanding accelerated motion. To determine the spacing of the nuts, use the formula:

$$\text{DISTANCE} = \tfrac{1}{2}\,\text{ACCELERATION} \times \text{TIME} \times \text{TIME}$$

$$d = \tfrac{1}{2}at^2$$

Normally 9.8 meters/second^2 would be substituted in this formula for acceleration. However, this will need to be scaled down so that this activity can be done in a classroom.

To determine the spacing of the nuts:

Use 9.8 centimeters/sec^2 for acceleration and 1, 2, 3, 4, 5 as intervals of time.

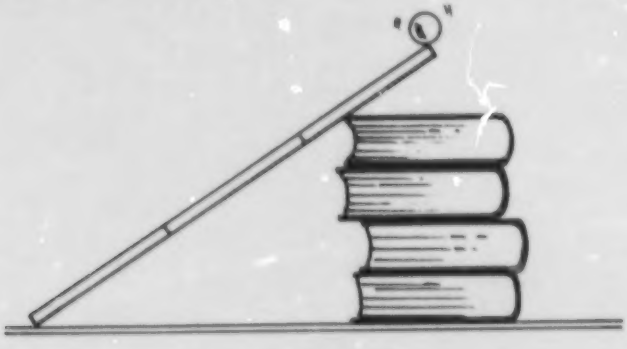
Spacing between the nuts will be measured in centimeters; however, the time interval will not be measured in seconds, just intervals of time. By substituting in the formula, you will get the following results for the distance. Next, round off the distance to the nearest whole number for the spacing of the nuts.

TIME	DISTANCE	NUT SPACING
1	9.8 cm	10 cm
2	39.2 cm	39 cm
3	88.2 cm	88 cm
4	156.8 cm	157 cm
5	245 cm	245 cm

Tie the nuts onto the string at these intervals. Before you have demonstrated this activity, ask the students to predict the sound that will be heard as the nuts hit the pie pan. Then have a student stand in a chair and drop the string and nuts so that these hit the pie pan.

- **Galileo's 17th Century Experiment**

This is Galieleo's 17th Century experiment that shed light on the study of accelerated motion utilizing very simple equipment. It is also an example of a physical science concept combining the use of the scientific method, mathematics, and measurement.



A trough three meters long, a metal ball, and a digital stop watch will be needed. Prop the trough on a pile of books so that the ball rolls freely down the inclined plane. Next, mark off sections of the trough in meter lengths. Determine the time it takes for the ball to travel one unit (1 meter), two units, and then, three units. Make a data table of your results.

DATA TABLE — DISTANCE vs. TIME

DISTANCE (units)	TIME (sec)	TIME X TIME (sec^2)
1		
2		
3		

Galileo did not have the advantage of knowing that:

DISTANCE = ½ ACCELERATION X TIME X TIME

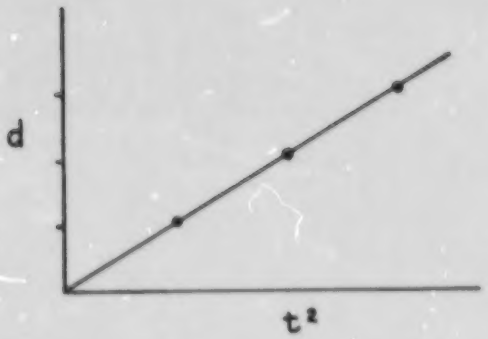
$d = \frac{1}{2}at^2$

He didn't know exactly what acceleration was or that it was a constant figure. He didn't have a fancy digital watch to use in taking his measurements. What he did prove by this experiment was that:

The distance an object falls is proportional to the time squared.

$d \propto t^2$

If these two quantities are proportional, a graph of the time squared plotted against the distance will be a straight line.

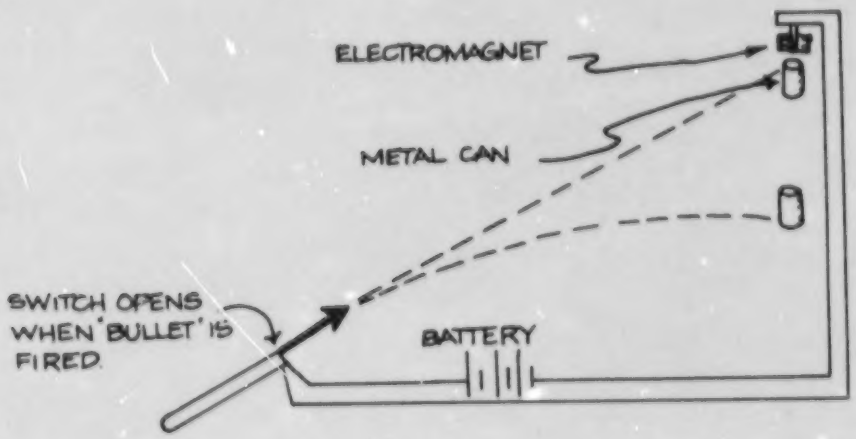


- **Shoot the Metal Can!**

This activity is a must for every secondary student. The equipment may be made; however, it can be purchased through a scientific company at a reasonable cost. This activity originated by an argument over the hypothesis that objects fall at the same rate regardless of their masses. This experiment was devised to settle once and for all this argument. The postulate was as follows: If an object were shot in a tree and if the object dropped at the same time the shot was fired, the bullet would hit the falling object. Have the students predict the results before you do the demonstration.

Set up the apparatus and make a diagram on the board so that the students understand the electrical wiring as well as the significance of objects falling at the same rate regardless of mass.

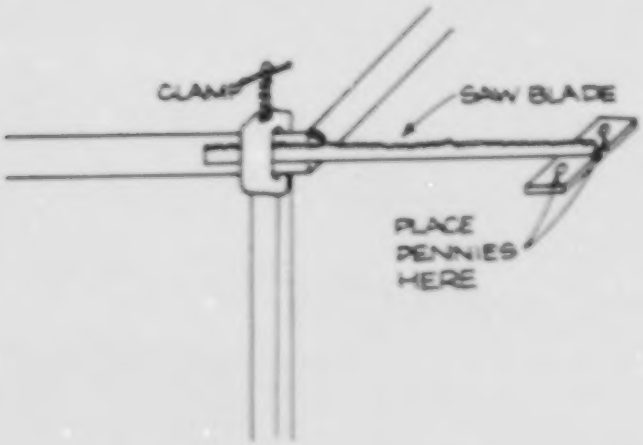
Relate this to dove shoots. By asking, where is the best place to aim the gun? How does the hunter allow for the motion of the bird?

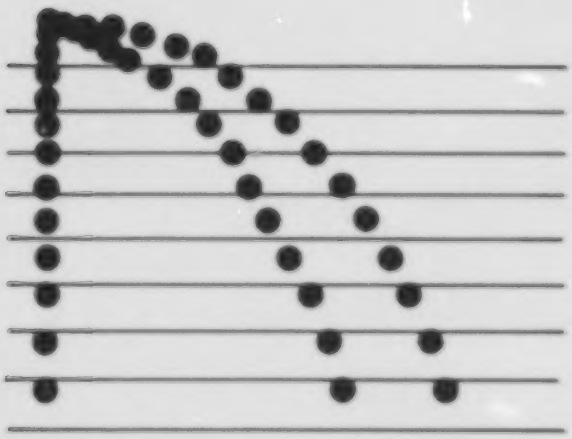


- **Drop One Shoot One!**

One metal ball will be dropped, while one ball will be projected horizontally. This activity will allow the students to see visually as well as hear both objects strike the ground at the same time. If you have purchased this apparatus, you will be able to shoot one of the metal balls out with a greater velocity. Demonstrate both of the horizontal velocities.

An easy-to-make apparatus can be acquired with an old hacksaw blade and a piece of metal soldered on one end of the blade. Place a coin on each side of the piece of metal that has been soldered to the hacksaw blade. Attach the blade to the lab table or desk with a C-clamp and pull it back a few centimeters. Turn loose! Did the coins hit the floor at the same time? (Yes) Try pulling the hacksaw blade back a little farther and turn loose. Was one coin projected, while one fell straight down? (Yes) Did these coins hit the floor at the same time? (Yes) Do objects fall at the same rate? (Yes)



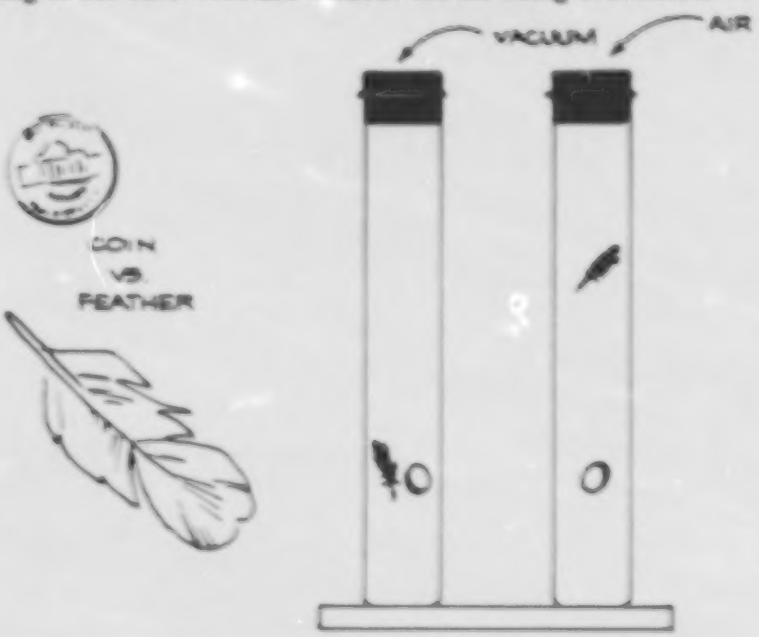


- **What Is the Best Angle for the Longest Range?**

Use rubber tubing connected to the spigot to demonstrate how water shot out at different angles will have different ranges. What is the optimum angle for the longest range? (45 degrees) How would you aim a 20 mm gun for the longest range? (45 degrees)

- **Coin and Feather Experiment!**

One of the best ways to demonstrate the principle that all objects fall with the same acceleration is by using the coin and feather apparatus with a vacuum pump. Once the air is evacuated out of the tube by the vacuum pump, the coin and feather will fall with the same acceleration. If a metal coin and a feather were dropped in the air, this would not occur due to the increased resistance of the air on the feather. Compare the difference in the air friction by demonstrating the motion of the coin and feather dropping in the tube with and without the air being evacuated.



• **Air Friction on Paper**

Take two pieces of paper. Crumple up one piece of paper. Hold the crumpled piece of paper in one hand and the second piece of paper in the other hand. Drop both pieces of paper at the same time. Which one landed on the floor first? (The crumpled piece of paper) What was different in the air friction on each piece of paper? (There was less air resistance with the crumpled piece of paper.) How do sky divers change their speed while descending?

APPLICATIONS AND IMPLEMENTATIONS OF LOCATION, VELOCITY, ACCELERATION, FREE FALL MOTION, AND PROJECTILE MOTION

Before the concepts of motion are introduced, make certain that students know how position or location is expressed as a coordinate relative to an origin. Students must relate their own location to their position on the map.

By the time these activities on speed and acceleration are completed, the students should be able to grasp the difference between velocity and acceleration. Remember when speed is given a direction, it becomes a velocity. Several additional classroom activities can provide the students with applications that they experience daily. Have the students determine the speed of race cars at the Darlington 500. Find out how the times are determined on track and field events at school, like the 440 yard, 880 yard, or one mile races. How do patrolmen determine the speed of your car on a highway? What was the average speed on your last trip to Myrtle Beach?

The concept of accelerated motion can be easily explained if you relate it to the automobile. The expression "put your foot on the accelerator" is used when you want to increase the velocity of your car each successive unit of time. When a body accelerates, its velocity changes over time. Acceleration also has direction.

As a result of students' completing the free fall and projectile motion activities, they should have a pretty good idea of the principles and laws associated with motion. Now these principles must be applied to situations observed daily.

If a hunter shoots a gun horizontally, will the spent cartridge of an automatic rifle hit the ground the same time as the bullet? (Yes) If you dropped a lead ball and an aluminum ball at the same time, which would hit the ground first? (Both will hit the ground at the same time.) Correlate this air resistance to the maximum velocity attained by a skydiver. What prevents the skydiver from going faster and faster? (Resistance of the air) What causes a skydiver to have a terminal velocity of 125-140 miles/hr? (Resistance of the air.)

How are cars designed to eliminate air friction? Compare the design of the box shaped cars of the 1920's with our sports cars of today. Do the new designs improve the gas consumption? (Yes, at high speeds). Compare the design of a transport plane like the Boeing 747 to that of the F-16 Falcon, a fighter plane. Which plane goes faster? (F-16)

At the end of the 4th down, what angle does a punter kick a football for maximum distance. If the team wants to increase their "hang time," what angle does the kicker use? Apply the principles of free fall and projectile motion to other sports such as tennis, soccer, baseball, track, and basketball.

What angle would you aim a cannon to get the longest range? If you were throwing a javelin, a discus, or shotput, what would be the angle you would aim for the greatest distance? If you are on a long fairway, which angle would you try to hit the ball for maximum distance? (A 45 degree angle would obtain the greatest range for a cannon shell, discus, and golf ball without air resistance.)

ACTIVITIES

- **Coke Bottle Inertia**

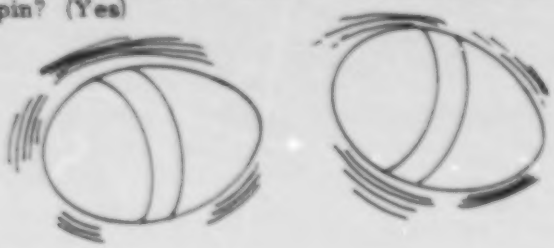
Newton's First Law of Motion: A body at rest remains at rest and a body in motion remains in motion unless acted upon by an outside force. Have the students prove the first part of this law to themselves: the tendency of a body to remain at rest.

This activity will make a good classroom demonstrations. Place a piece of paper or a dollar bill between two soft drink bottles as illustrated. Quickly snatch the paper from between the bottles. What happened? Try it again. You may need to moisten the mouths of the drink bottles.

The drink bottles are at rest. The motion of the paper is not enough force to overcome the inertia and put the bottles in motion. Therefore, the bottles remain at rest. This property of matter is called "Inertia." It states that a body in motion remains in motion and a body at rest remains at rest unless acted upon by an outside force. Find out the part that Galileo played in the development of this principle.

- **Inertia of L'eggs**

Fill one L'eggs "egg" with water and tape it securely. Tape another L'eggs "egg" so that both eggs look alike. Have a student spin each of the eggs. In what ways do the eggs act alike when you try to spin them? How do they act differently? Is the one filled with water harder to spin? (Yes)



This activity illustrates inertia, which is stated in Newton's First Law of Motion. The concept of inertia says that a body at rest remains at rest unless acted upon by an outside force, or a body in motion remains in motion unless acted upon by an outside force. The water filled egg is harder to spin because it has to overcome more inertia than the egg filled with air. It is also harder to stop once it is set in motion.

- **Egg Drop**

Package a raw egg in a container no larger than 6" X 6" X 6", so it can be recovered unharmed when dropped from a height of 30 feet. The shell and yolk should not be broken. The package must weigh at least 1 pound.

Have the students do their packaging at home using any material they can find. Allow each student to explain their packaging material to the class. Locate a place where the eggs can be dropped. A ladder could be used or a second story window. Drop each one separately, but do not have the students open their package until they get back into the classroom. After all the students are back in the classroom, have them one by one open their egg drop package to see if their egg is still intact. Be sure to have a container for the broken eggs. Those eggs that are not already broken, put in a safe place or break them immediately.

NASA has correlated the dropping of the eggs in this activity to the launching of delicate instruments and soft-landing on the moon and planets. They had to develop a method to package instruments in lightweight containers in order to protect them from the dynamic forces of the space flights.

APPLICATIONS AND IMPLEMENTATIONS OF NEWTON'S FIRST LAW OF MOTION

These were examples of Newton's First Law of Motion which states that a body in motion remains in motion and a body at rest remains at rest unless acted upon by an outside force. The coke bottles were at rest and remained at rest as you snatched out the paper that was between them. Don't magicians do the same thing when they snatch the table cloth out from under the dishes? Find out what kind of cloth the magicians use.

When you tried to spin the L'eggs "eggs," the one that was filled with water resisted the motion, as all of the water has to be set in motion. Once these are both in motion, which one stops first? Correlate the Egg Drop activity with packaging delicate instruments for space flights and soft-landings on the moon. Why are "peanuts" (styrofoam bits) used for packaging science laboratory equipment when shipping?

Why do you "buckle up" your seat belt when you get into a car? What happens when you stop suddenly? (If the car was to stop suddenly or be hit by another vehicle, the inertia of your body would keep it moving forward. The seat belt will keep your body in the seat and protect you from injury.)

When standing in a school bus, how do you brace yourself for a sudden stop? When the bus stops, which way do you go? A body in motion remains in motion unless acted upon by an outside force. Did your body keep moving forward? (Yes)

When a school bus lunges forward, your body is at rest and remains at rest. Your body is not in motion and at first you tend to be pressed against the back of the seat. The first part of Newton's Law states that, "A body at rest remains at rest unless acted upon by an outside force." This is exactly what happens. Your body remained at rest until it was acted upon by an outside force (the force of the school bus).

Why are the bumpers on newer model cars called "Inertia Bumpers"? Examine these bumpers carefully to see how these cushion a small crash.

ACTIVITIES

- **Comparison of Forces Needed to Stop an 18-Wheeler and a Compact**

Newton's Second Law of Motion states that force is proportional to the mass times the acceleration.

Force = Mass X Acceleration

In order to accelerate a massive truck, the force is proportional to the mass. What would happen if you put the engine of a compact car in an 18-wheel truck? (The force of the engine would not be enough to accelerate the more massive vehicle.) It takes a lot more force to accelerate the truck than to accelerate a compact car. Therefore, the truck's engine must provide a larger force. Similarly, it takes a lot more force to accelerate a space rocket than an airplane.

Compare the type of brakes needed to stop an 18-wheeler truck, a medium size car, and a bike. What type of brakes are needed by each of these vehicles? (An 18-wheeler requires air brakes, a car needs hydraulic brakes, and a bike can be stopped with mechanical brakes.) Because the 18-wheeler is more massive, it needs more breaking power than a car. In turn a more massive car needs more breaking power than a bike.

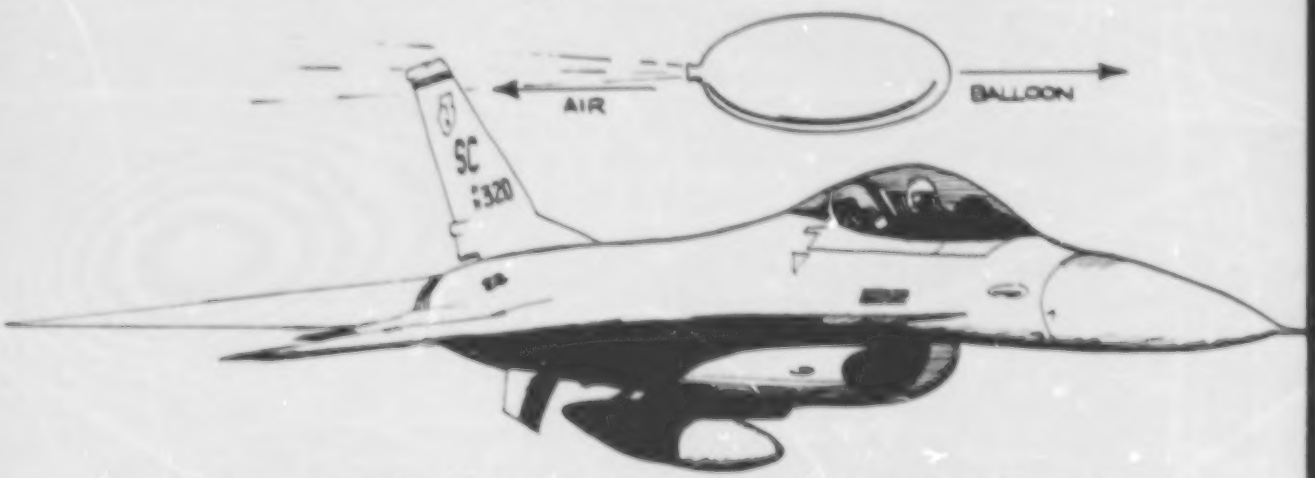
APPLICATIONS AND IMPLEMENTATIONS OF NEWTON'S SECOND LAW

Apply Newton's Laws to golfing, baseball, or your favorite sport. Examine the shapes of golf irons and woods to determine the use of each. Why are the woods used for long drives? Why are irons made with different angles? What is the difference in the batter's swing when a ball is bunted and when a homer is hit? Why are different weights and lengths of bats used? How is the greatest force applied? Now use Newton's Second Law as it applies to tennis or soccer.

ACTIVITIES

- **Can You Demonstrate Newton's Third Law with a Balloon?**

For every action, there is an equal but opposite reaction! Blow up a balloon. When you turn the balloon loose, which direction does it go? Why does it go in that direction? (As the air leaves the balloon in one direction, an equal but opposite force pushes the balloon forward in the opposite direction.)



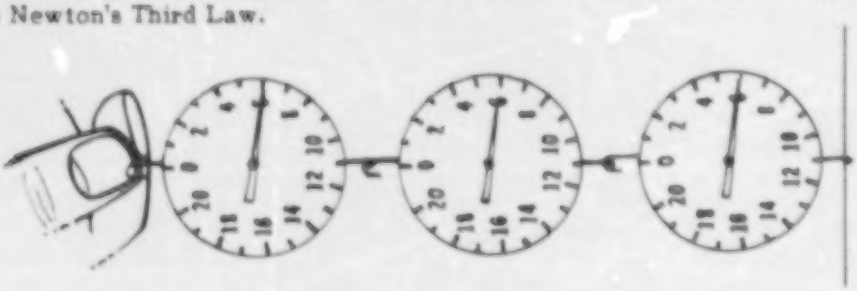
This same concept explains how jets work. As the gases leave the engine of a jet, the plane goes forward. Newton's Third Law of Motion explains that for every action, there is a equal but opposite reaction. Ask your students to think of other examples of this equal but opposite reaction.

- **When are Forces Equal?**

This activity should take place in the school yard. Select two teams of three students with equal masses. Have a "Tug of War" using a ski rope. If these teams are pulling with equal forces then the ski rope will not move. Now have one student turn loose. What happened to the forces? Next, select a team that is much smaller. What happens when the forces are not equal? How does Newton's Third Law of Motion explain this action?

- **Does the Wall Exert a Force?**

Attach three large spring scales to one another and then hook the last one onto the wall. Now gradually pull on the spring scale. Is the force equal on each spring scale? What is the force exerted on the hook in the wall and what is the direction? Apply the Newton's Third Law.



- **Use Indian Wrestling to Explain Newton's Third Law**

Have two students Indian wrestle. They are applying Newton's Third Law of Motion. Often called the "Law of Action and Reaction," it states that for every action, there is an equal but opposite reaction. As the two students try to prove their strength, they are applying an equal but opposite force.

Isometrics is another good example of Newton's Third Law. Different muscles of the body work against each other. One muscle provides the action while another muscle provides the reaction. What other examples of Newton's Third Law can you find?

APPLICATIONS AND IMPLEMENTATIONS OF NEWTON'S THIRD LAW OF MOTION

Why does a small boat scoot out from under you as you jump out? As a gun is fired, why does it have a recoil? When you turn loose a blown up balloon, which direction does it go? These are all examples of Newton's Third Law of equal but opposite forces which states that for every action there is an equal but opposite reaction.

Does the floor exert an equal but opposite force as you walk on it just like the students in tug of war? What would happen if the floor didn't exert an equal but opposite force? (You would fall through the floor.) Does a hook on the wall holding up a picture exert an equal but opposite force on the wall? (Yes!) When you kick a football, does the ball exert a force on your foot? If you said no, then try kicking a brick bat! Look for other examples of Newton's Third Law of Motion.

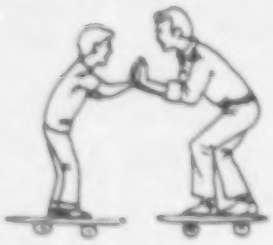
ACTIVITIES

- **Conservation of Momentum**

This activity will require two momentum carts or skate boards. Select two students of equal masses to sit on the momentum carts or stand on the skate boards. Have the students face each other with their hands in front and push off. If the students are about the same mass, they will go about the same velocity. Now select a very small student and one that is very heavy. Have these students push off. Was there a difference in their velocity?

Momentum = Mass X Velocity

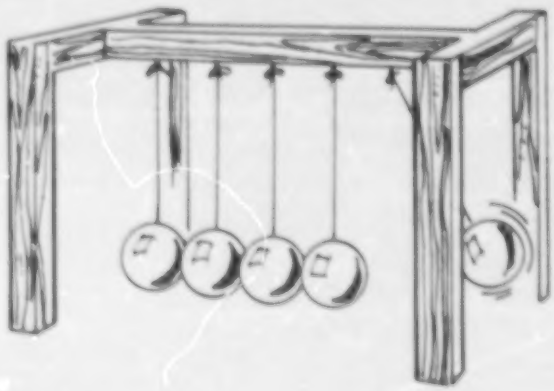
Momentum (Cart 1) = Momentum (Cart 2)
Mass X Velocity(Cart 1) = Mass X Velocity (Cart 2)



Without using numbers, have the students realize that the smaller student must go faster because momentum is always conserved.

- **Momentum Conservation of a Toy Pendulum**

Apply the Law of Conservation of Momentum to the toy pendulum. This toy has 5 balls suspended in such a way that each swings independently. As one ball is pulled out and turned loose, it will knock out one on the opposite side. When two balls are pulled out and released, how many are knocked out on the other side? (When 2 balls are turned loose, 2 balls will be knocked out.) Try releasing three balls and then 4 and 5 balls. (When 3 balls are turned loose, 3 balls will be knocked out; 4 balls will be knocked out when 4 are released; and 5 balls will swing when released.) Remember that momentum is always conserved. The mass times the velocity of each of the balls released will always equal the mass times the velocity of the balls that are knocked out.



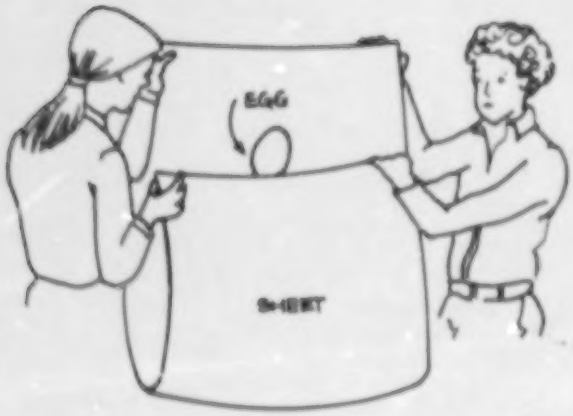
- **Is Momentum Equal to Impulse?**

You will need a large bed sheet, an egg, and several students that have a pretty good throwing arm. Have two students hold a sheet so that it forms a pocket to catch the egg. Next have a student throw the egg against the sheet. Is the egg all right? The formula for momentum is mass times velocity. The formula for impulse is force times time. These are equal!

MOMENTUM	=	IMPULSE	
MASS X VELOCITY	=	FORCE X TIME	
MASS (egg) X VELOCITY (egg)	=	FORCE (egg hits) (the sheet)	X TIME (egg is hitting) (the sheet)

As the small egg is thrown with a large velocity, this is equal to the small force it hits over a long period of time. Have several of the athletic students throw the egg with their best pitch. Just make certain they hit the sheet each time!

Apply this to the inertia bumpers that are on the new cars. The force of impact acts over a longer period of time. Therefore, very little damage is done to either car or the individuals in the cars.



APPLICATIONS AND IMPLEMENTATIONS OF MOMENTUM CONCEPTS

Conservation of momentum is really Newton's Third Law. Momentum is the mass of an object multiplied by its velocity. In a collision the mass times the velocity of one object is equal to the mass times the velocity of the other object. The momentum carts illustrate that when forces are equal, the velocity of the carts are dependent upon the masses of the students. No matter what you changed, the Mass X Velocity of each cart was equal or conserved. As different size students pushed off, the velocity of each cart was different. Did the larger student have a smaller velocity? (Yes) Examples of conservation of momentum are present every time there is an accident. Why does the truck have a decided advantage in a crash with a compact? (Because of its mass) When demonstrating the pendulum toy, the number of balls knocked out is equal to the number of balls released. Here again momentum is conserved.

By equating impulse to momentum, several daily occurrences can be easily explained. Impulse is force times time. Impulse is equal to momentum.

IMPULSE = MOMENTUM

FORCE X TIME = MASS X VELOCITY

When the egg hit the sheet over a long period of time, the force became smaller. The force multiplied by the time was equal to the mass times the velocity of the egg. Therefore, the time was lengthened and the egg did not break. The same thing occurs when a baseball player catches a ball. The player's hand moves back as the ball is caught. Parachutists bend their knees as they land to break the fall lengthening the time of impact.

• Where Is the Center of South Carolina?

Cut out a road map of South Carolina, and glue it to a heavy piece of cardboard. Cut the cardboard along the outside edges of the map. Now poke a hole in each corner of the map, as shown in the illustration.

Suspend a heavy fishing weight from a nail with a piece of string. You will need a pencil to mark the position of the string. Hold the map upright. Place the nail in a hole, carefully mark the position of the string as the fishing weight holds the line taut. Rotate the nail to each hole, marking the position of the line from each corner of the map.

After you have drawn a line from each of the four corner holes, look at the place where the lines intersect or meet. Where is the geographical center of South Carolina? (Columbia or more specifically Horrell Hill.) Try balancing the map of South Carolina by placing a finger under this spot.

Examine maps of other states to find out how many states in the country have the capital located in its geographical center.

- **What Does the Center of Gravity Have to Do with Wheel Balancing?**

Cut out a number of objects from a heavy piece of cardboard. Make certain you have objects in the shape of a square, a rectangle, an "L," a circle, and an ellipse as well as several irregularly shaped objects. Now poke a hole in each corner or around the edge of these objects.

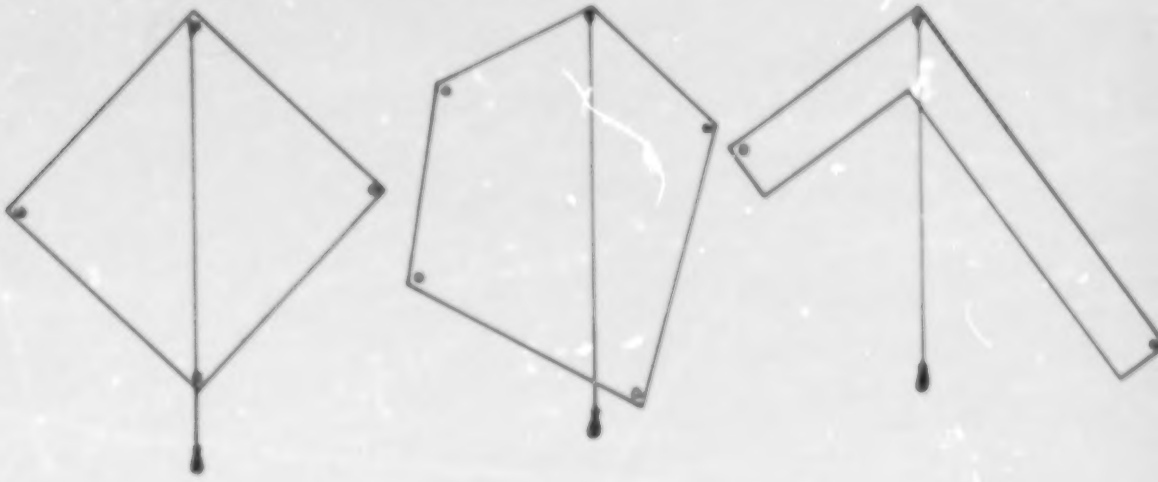
Suspend a heavy fishing weight from a nail with a piece of string. Have a pencil handy to mark the position of the string. Place the nail in a hole and allow the plumb bob and string to hang freely against the objects. Mark the position of the string. Rotate the nail around to each hole, marking the position of the string each time.

After you have drawn lines from each end of the corner, look at the place where the lines intersect. This is the center of gravity of your object. Is the center of gravity within the object? If it is, see if you can place your finger under the object and balance it from that point. Does the center of gravity have to be within the object? (No) Where is the center of gravity of the "L"?

Where is the center of gravity of your body when you are running? I hope it is over your feet! Where is the center of gravity of a pole-vaulter? Sometimes they jump in such a way that their center of gravity remains beneath the bar. How could this be?

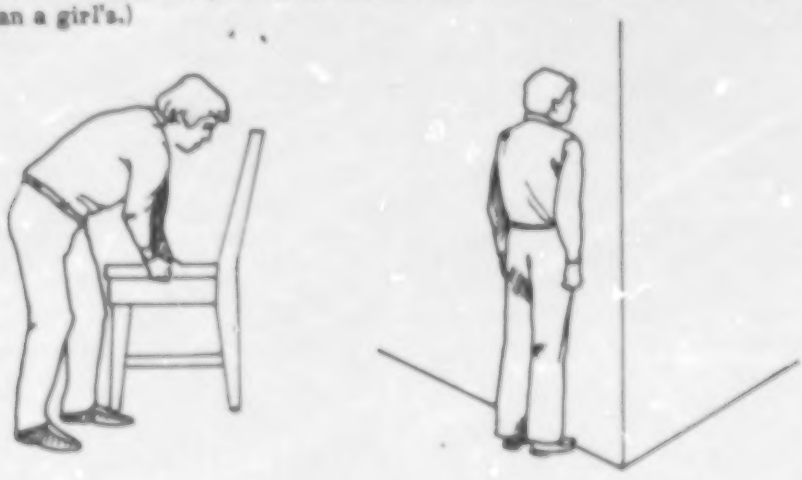
Where is the center of gravity of a boomerang? Where is the center of gravity of a doughnut? Where is the center of a tightrope walker holding a weighted bar in front of him? Where is the center of gravity of the Leaning Tower of Pisa? Where is the center of gravity of a meter stick? Balance it with your finger at that point. Balance a pencil with your finger.

Why are automobile wheels balanced? What happens to the motion of the car if the wheels are not balanced? Of course, a plumb bob is not suspended from the nail to balance the wheels of a car. Dynamic balancing is used where the wheels are spun around rapidly and a strobe light indicates where the wheels are not balanced. Then metal weights are added to balance your wheels.



- **Is the Center of Gravity Different for a Male and Female?**

Select a macho type male student with well developed shoulders and small hips. Have him stand flat-footed facing an outside corner wall. Now ask him to stand on his toes. He will not be able to do it. Next, ask a petite girl to try the same thing. She should be able to do it. Why is there a difference? Where is the center of gravity of each student? (The center of gravity of a macho male should be much higher in the chest cavity than a girl's.)



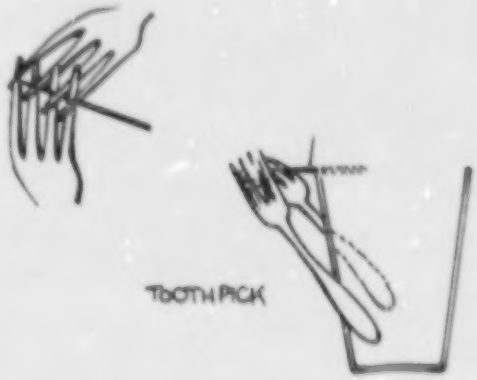
Place a chair with its back against the wall. Have the macho student facing the chair lean over it and support his head against the wall. Now have him try to lift the chair off the floor. His center of gravity should be in such a position that it is impossible for him to lift the chair. Now ask a petite girl to lift the chair in the same manner. Why is there a difference?

- **Center of Gravity as It Affects Stability**

Have several students stand with their heels against the wall and try to pick up small objects placed on the floor in front of them without bending their knees. What happens?

- **Center of Gravity and Stability**

Use this activity as a classroom demonstration. Interlock the tines of two table forks, insert a toothpick as shown and balance the combination on the edge of a drinking glass. Now light the end of the toothpick extending inside the rim of the tumbler. The toothpick will burn to the glass leaving a precarious but quite stable balanced arrangement. Blow on it gently to make it rock. Discuss the position of the center of gravity of this combination.



APPLICATIONS AND IMPLEMENTATIONS OF CENTER OF GRAVITY

The center of gravity is the point where an object's weight is evenly placed. It is the place on an object where it can be balanced without a tendency to rotate. Everything that has a mass has a center of gravity. Bridges, buildings, and cars all have a center of gravity. Many examples of the use of center of gravity can be seen daily. Why is the engine placed low between the wheels of an automobile? Why does a kite have a tail? How does a surveyor use a plumb bob? When you lift up something heavy, why do you pick it up under its center of gravity? In a circus high wire act, what is the purpose of the girl hanging under the motorcycle? In a tight rope act, what is the purpose of the long pole with weighted ends?

Why do cars and jeeps with a narrow wheel base turn over easily? (Some postal cars have a narrow wheel base.) What happens to the center of gravity when you change the wheels to high riders? Will the vehicle have the same stability or does it have a tendency to turn over easily?

Because the center of gravity is a more familiar term, it has been used rather than center of mass. The center of gravity is the point around which all the weight of the object is distributed. As long as we are in a uniform gravitational field, mass and weight are proportional. Therefore, the center of gravity and center of mass are the same. However, the greatest difference in understanding these terms is in planetary motion, where the center of mass and the center of gravity are not the same. The center of mass of the solar system lies within the massive sun causing it to wobble as the planets move in their orbit. Because the wobble of nearby stars has been detected, astronomers realize that these stars must have a planetary system causing this motion. Center of gravity was used because of its familiarity to the students. However, it is important for the students to recognize the difference between center of gravity and center of mass.

- **What Is Your Horsepower?**

For this activity, you will need to have a stop watch and access to a flight of stairs as well as know the weight of the student in pounds. You will also need a ruler to measure the height of the stairs in feet. Use a stop watch to determine how fast a student can climb the flight of stairs. Plug your figures into this formula:

$$\text{Power} = \frac{\text{height}_{(\text{stairs})} \times \text{weight}_{(\text{student})}}{\text{time}}$$

$$\text{Your Horsepower} = \frac{\text{Power}_{(\text{ft-lbs/sec})}}{550 \text{ ft-lbs/sec}}$$

Example: Your weight = 137 pounds
Flight of Stairs = 15 feet
Time to climb the stairs = 7 seconds

What is your horsepower?

$$\text{Power} = \frac{137 \text{ pounds} \times 15 \text{ feet}}{7 \text{ seconds}} = 293 \text{ ft-lbs/sec}$$

$$1 \text{ Horsepower} = 550 \text{ ft-lbs/sec}$$

$$\text{Your Horsepower} = \frac{293 \text{ ft-lbs/sec}}{550 \text{ ft-lbs/sec}} = .53 \text{ hp}$$

About ½ horsepower was developed in climbing this flight of stairs. Compare this figure to the horsepower of your family car, lawnmower, or boat motor.

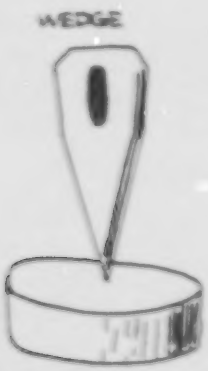
APPLICATIONS AND USES OF HORSEPOWER

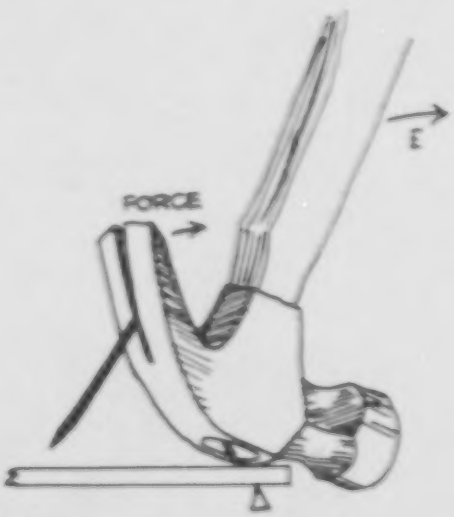
Find out how horsepower was first determined. Compare this to the way it is determined now. What are the horsepower ratings of cars, lawnmowers, motor cycles, trucks, airplanes, and tractors? Compare the use of each of these vehicles to the velocity and acceleration necessary for operation. Do the same with tools such as lawnmowers, drills, skill saws, and cultivators by comparing the speed necessary for operation and use.

• Locating Six Simple Machines!

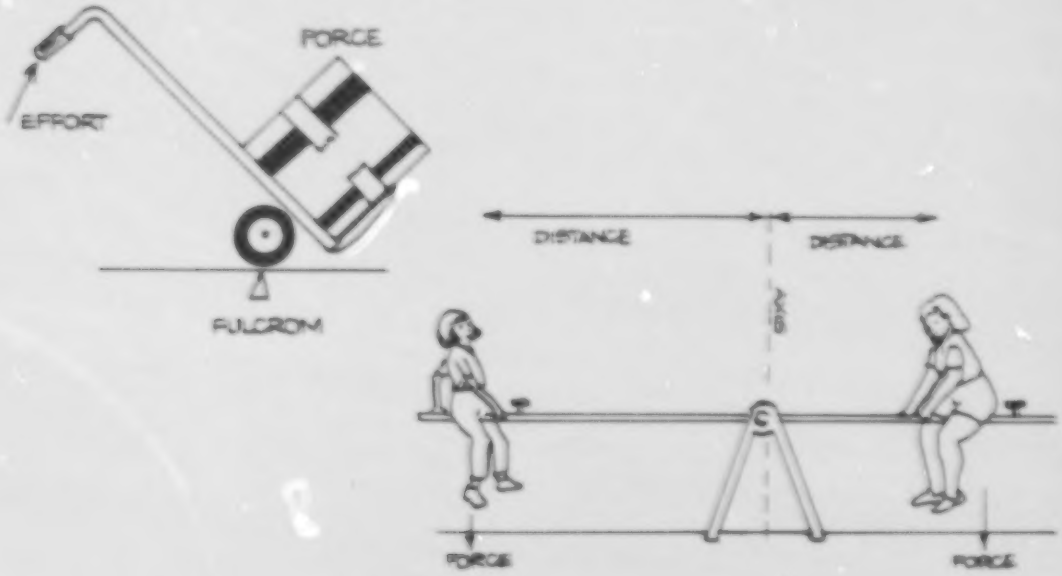
Simple machines are used daily by everybody to make work easy. Each of the six simple machines should be demonstrated. Then ask the students to look around them and identify examples of simple machines they use daily.

The lever should be demonstrated with a 2" by 4" wooden timber about 6 feet long placed over a small strip of wood. First try two students of equal masses on each end. Then use two students of different masses and let the class see where the smaller students must be placed for them to balance. If a seesaw is available, use this as a demo.





Differentiate between 1st, 2nd, and 3rd class levers by demonstrating the use of a hammer, screwdriver to open a paint can, wheel barrow, nut cracker, fishing pole, baseball hitting a bat, and hand truck. A knife or chisel can be used as an example of a wedge. Handicap ramps and conveyor belts are examples of the inclined plane. A variety of screws with different threads and drill bits should be collected as examples of the screw. Pulleys can be collected from old windows. Old toys can be saved as examples of the wheel and axle.



• What's Under the Hood?

The use of old auto parts in demonstrating the function of an engine is imperative. From an auto junk yard, gather up parts such as a carburetor, hydraulic brake cylinder, voltage regulator, generator, alternator, spark plugs, ignition coil, distributor, and cylinder sleeve with a piston. Use these old parts along with a diagram found in an automobile repair manual to explain the function of the electrical, hydraulic, and combustion systems.

APPLICATIONS AND COMPARISON OF MACHINES

Collect a number of items that use a combination of simple machines such as an egg beater, a broken watch or clock, an old pencil sharpener, a can opener, an old door knob and lock, a key, and scissors. Ask the students to identify the simple machines in each item.

Locate an old lawn mower motor to use in identification of parts. The size of this motor makes it excellent for classroom use especially when explaining the combustion system of the automobile.

UNIT XI
WAVE MOTION, SOUND, AND LIGHT

OBJECTIVE

The students will demonstrate an understanding of the behavior of sound and light through mechanical wave motion and relate these properties to every day experiences.

TEACHING STRATEGIES

Relating something that everyone has seen like ripples on a pond to wave motion properties demonstrates in a visual manner properties of both sound and light. A ripple tank has become a very useful tool in illustrating linear propagation (straight line motion), reflection, refraction, diffraction, and interference patterns. A variety of ripple tanks can be purchased but in the activity PROPERTIES OF WAVES DEMONSTRATED WITH A PIE PAN RIPPLE TANK, a very simple ripple tank can be made and demonstrated on an overhead projector.

Sound and light have very different properties yet the transmission of both can be better understood by studying mechanical waves. By using a slinky to demonstrate the movement of waves in WHAT IS A SOUND WAVE?, students will be able to grasp an understanding that sound waves are longitudinal or compressional waves. Now demonstrate transverse waves in CHARACTERISTICS OF LIGHT WAVES ILLUSTRATED WITH A SLINKY. These two types of waves have very different properties. Sound vibrates matter and therefore needs a medium to travel, while light can travel through space without a medium. Be sure to liken the motion of sound waves to longitutinal waves and light to that of transverse waves.

Sound wave properties can be demonstrated in VIBRATING MATTER WITH A TUNING FORK!, SIMULATE VOCAL CORDS BY USING A BALLOON!, DO SOUND WAVES TRAVEL BEST THROUGH A SOLID, LIQUID, OR GAS?, CAN YOU HEAR THE BEATS?, and WHAT IS THE SPEED OF SOUND IN THE CLASSROOM? The rest of the activities demonstrate properties of light.

It should be pointed out that one of the great debates in the history of science was whether light was composed of waves or particles. Sir Isaac Newton believed that a beam of light was a stream of particles. One of his reasons was that light formed a distinct shadow. Therefore, light had to be made of particles. Waves would have a fuzzy edge on the shadow. About the same time, Christian Huygens developed the theory that light traveled in waves. He reasoned that a shadow was cast because of the very small size of the waves. This debate continued for many years until the duality of light was recognized and the nature of light evolved as a combination of waves and particles called photons. The particle theory is now called quantum mechanics. As the activities are developed, be sure to discuss which properties illustrate light as either a wave or a particle.

ACTIVITIES

• Properties of Waves Demonstrated with a Pie Pan Ripple Tank

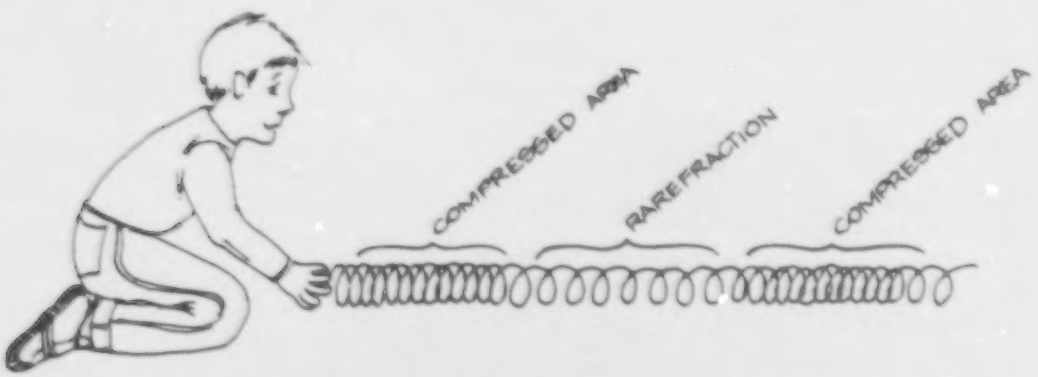
A ripple tank has become an excellent tool for illustrating wave motion properties of sound and the electromagnetic spectrum as these travel very much like ripples in a pond. When a fish nibbles the bait on the end of a fishing line, a circular wave pattern is set in motion. A ripple tank can be made by placing a few centimeters of water in a clear glass pie dish and then placing it on an overhead projector. Try different amounts of water in the pie dish until the ripples can be clearly seen by the students. The waves should be magnified so that when the light is turned on all the students will be able to observe mechanical wave motion properties. Demonstrate one pulse by tapping the water with your finger in the middle of the pie dish. Reflection is immediately observed. Waves can be generated with a constant motion of one finger. Objects can be placed in the pie dish to simulate diffraction properties just as waves act going around the pilings of a pier.

Young's double-slit interference pattern can be demonstrated by using an electric knife as a wave generator and taping two nails to the blades a few centimeters apart. Then attach a dimmer switch to the electric cord. The dimmer switch will allow you to vary the speed of the blades so that the wave patterns can be clearly observed. Point out the nodes and antinodes of the interference patterns.

• What Is a Sound Wave?

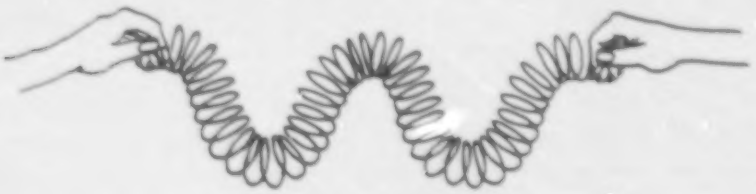
A slinky will help you understand a sound wave. Put the slinky on the floor, and give it a push and a pull. Keep doing this for a few seconds. Do you see the areas where the slinky coils are close together? This is the compression area. Do you see the areas where the slinky coils are far apart? This is the rarefraction area. The same thing happens when a sound wave is passing through the air. Sound waves are produced by vibrating matter setting up areas where the sound compresses the air molecules and other places where the air molecules are farther apart or rarefracted.

When you strike a tuning fork, the vibrating object sends a wave in the air that is made up of compressional and rarefracted areas that causes your eardrum to vibrate thus creating the sound that you hear. These compression waves are referred to as longitudinal waves.



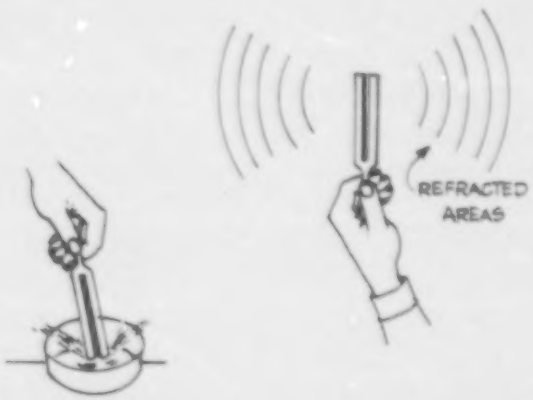
- **Characteristics of Light Waves Illustrated with a Slinky**

Demonstrate the motion of light waves by using a large slinky. Stretch the slinky on the floor with a student holding the other end. Put the slinky in motion by moving your hand back and forth on the floor giving it a sideways motion. If the flooring is tile blocks, line up the motion of this transverse wave so that the students can determine the wavelength and amplitude. The wavelength can be measured from crest to crest or trough to trough. One pulse can be generated or a standing wave can be demonstrated by giving the slinky a single or constant back and forth motion. Vary the speed of the wave to demonstrate the variation in wavelength and amplitude. Point out the reflection of the wave as it goes through the slinky and returns diminished in size. Next attach a lightweight cord to the end of the slinky to demonstrate refraction as the waves move from one medium to another. Did reflection occur?



- **Vibrating Matter with a Tuning Fork!**

Strike a tuning fork with a rubber mallet. Quickly place the tuning fork in a few centimeters of water. The students may not be able to see the prongs of the tuning fork vibrate from their seat but when this is placed in water the vibrations are clearly visible. This activity will make it easy to understand that sound is vibrating matter. Make this even more dramatic by using a clear pie dish that has been placed on the overhead projector. The motion of the water will be quite visible.

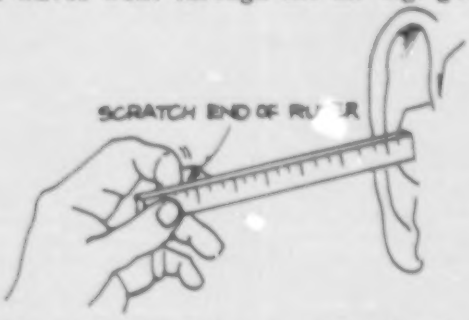


- **Simulate Vocal Cords by Using a Balloon!**

Blow up a balloon. Slowly allow the air to escape by stretching the neck of the balloon. As this is done, a high frequency sound should be audible. Vocal cords act very much the same way. We stretch the vocal cords in the back of our throat to make different sounds as we breathe through the cords.

- **Do Sounds Waves Travel Best Through a Solid, Liquid, or Gas?**

Have the students place a wood or plastic ruler to their ear. Then instruct them to scratch the outside end of the ruler with their fingernail. Now have them move the ruler away from their ear while scratching the same distance from their ear. Did they hear the scratching sound better (louder) when the ruler e.g. solid was against their ear or when the sound waves went through the air e.g. gas? (Sounds travel best (faster) through solids.)



Next, have the students strum a rubber band while holding one end by their teeth. Then compare this to the sound they hear when they are strumming the rubber band between their fingers. Which medium is best for transmitting sound? (Solid teeth and bones) How did the Indians know when someone was coming? (They put their ear to the ground to listen for the sound of horses). How did the cowboys know when a train was coming? (They listened to the sounds transmitted through the rails).

When students are swimming in a lake or pond, do they hear a boat motor better while under the water than they do when their head is out of the water? (Under the water) Is sound transmitted better in liquids (water) or in a gas (air)? (Liquid)

The students will see that sound travels better through solids than liquids and next through air. What is the speed of sound in air, water, and a solid such as iron? (The speed of sound in air is 346 m/sec, water is 1498 m/sec, and iron is 5200 m/sec all at 25°C.)

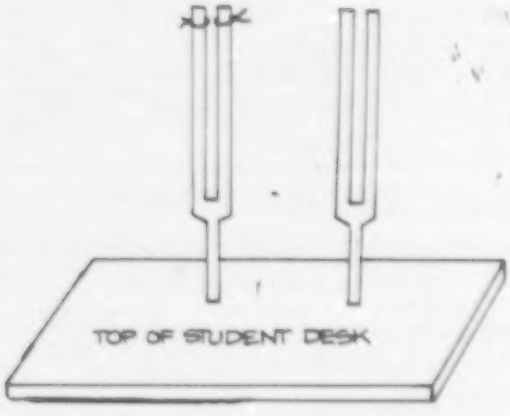
- **Can You Hear the Beats?**

When two tones of slightly different frequencies are played together, a different sound is heard. It sounds like a "wong, wong." Many band students will be familiar with this periodic sound, as they have been trained to tune their instruments by listening for this "wong, wong" sound when playing the same tone as another instrument that has already been tuned. The longer the time interval between the "wong, wong" sounds, the closer the instruments are in tune. As the instrument becomes closer in tune to the correct pitch, the time interval between "wong, wong" sounds are increased until the "wong, wong" sound is eliminated when the pitch is identical to the previously tuned instrument.

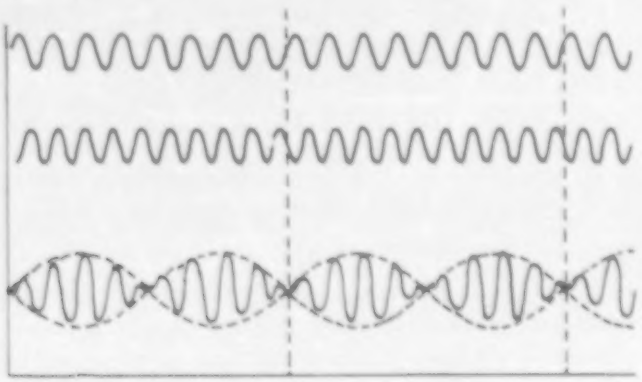
These beats can be demonstrated in class with two tuning forks of the same frequency. Before the class begins, add a piece of wire to both ends of the tines by twisting each end tightly. Try the tuning forks out until you hear a distinct "wong, wong" sound when both are struck at the same time. An empty student desk makes an excellent sounding board for hearing beats.

To reinforce this concept of tuning with beats, have two students that play the same instrument bring these to class and demonstrate how they tune their instruments by using beats.

A small piece of wire twisted on each tine will change the frequency of the tuning fork.



Beats occur because you are sounding two tones with slightly different frequencies. The combination of these tones is due to interference. The vibration of the two tuning forks are first in step and then out of step. The addition of the two waves constructively combine to make a beat at periodic intervals. This is why the beats occur in definite intervals.



- **What Is the Speed of Sound in the Classroom?**

Being able to determine the speed of sound in the classroom with fairly simple equipment will give an added dimension to understanding the rate that sound travels. You'll need a plastic milk jug, 2.5 cm (1 inch) PVC pipe about 35 cm long (14 inches), and mallet along with several different tuning forks.

Fill the milk jug with water. Place the PVC pipe in the milk jug. Now hit one of the tuning forks with the mallet and hold it a few centimeters above the PVC pipe. As the fork is vibrating, adjust the height of the pipe and turning fork. When the length of the column inside the PVC pipe is right, the vibrating tuning fork will cause a sympathetic vibration in the pipe that magnifies the sound. This is called resonance. This first occurs when the length of the PVC pipe is ¼ the length of the sound wave. When the natural vibration rates of two objects are the same, resonance occurs. The water serves as a way of adjusting the length of the column of air inside the pipe by closing off one end. This is called closed tube resonance.

Try several different tuning forks to illustrate the difference in length of the PVC pipe that is necessary for resonance. The length of the column will be about ¼ the wavelength of the sound wave for the tuning fork. By measuring the length of the PVC pipe and multiplying by 4, this will give you the wavelength of the sound wave. Now multiply this wavelength by the frequency stamped on the tuning fork and you will have determined the speed of sound in your classroom.

Example:

Determine the speed of sound in the classroom by measuring the length of the PVC tube when resonance occurs. If you use the tuning fork C in the key of C, you'll get the following results. The tuning fork C vibrates at the rate of 256 hertz. Careful measurements will give you the length of the column of air in the PVC pipe. This is 33.5 centimeters when the temperature is 20°C or 68°F.

Wavelength = 4 X length of the air column

$\lambda = 4\,l$

Velocity = Wavelength X frequency

$v = \lambda \times f$

Where:

λ = lambda (Greek) is the symbol that represents the wavelength

l = length of the air column in the PVC pipe

l = 33.5 centimeters or .336 meters

f = 256 hertz or vibrations per second

Substituting in $\lambda = 4\,l$

$\lambda = 4 \times .335$ m

Wavelength = 1.34 meters

The length of the sound wave for the tuning fork C is 1.34 meters.

Substituting in the formula $v = \lambda \times f$

$v =$ 1.34 m X 256 hz

$v =$ 343 m/sec

Experimental speed of sound = 343 m/sec

Now, mathematically determine the speed of sound in the classroom. The speed of sound is 331.5 m/sec at 0°C. As the temperature rises, there is an increase in speed of 0.6 m/sec for each degree.

Example: Temperature in classroom = 20°C (68°F)

$$\frac{.6 \text{ m/sec}}{1^{\circ}\text{C}} \times 20^{\circ}\text{C} = 12 \text{ m/sec}$$

12.	m/sec	Change in speed between 0°C and 20°C
+ 331.5	m/sec	Speed of Sound at 0°C
343.5	m/sec	Computed Speed of Sound in the Classroom

Compare this speed of sound to the experimental speed of sound that you have just determined. Experimental results should be close but do not have to be exactly the same. What is the speed of sound dependent upon? (Temperature in the room and media.)

You have used the formula for determining the speed of sound in your classroom using a closed tube. Sounds can also resonate through open tubes. Many band instruments such as a trumpet, trombone, and flute use this same principle of both open and closed tube resonance. Ask the students to check the organ at their church to see if it has open or closed pipes or a combination.

- **See Yourself from Head to Toe!**

Does it take a full size mirror to see yourself from head to toe? (No!) It only takes a mirror one-half your height to see ALL of you--your head and your toes providing the top of the mirror is the same height as the top of your head. This is because the angle of incidence is equal to the angle of reflection, the First Law of Reflection.

Many clothing stores use full length mirrors while others cut off your head so that you only see the clothes you are trying on. Most shoe stores only allow you to see your feet. If you have a full length mirror in your school, cover up part of the mirror with paper so that the students only use the part from their waist to the top of their head.

What distance are you from the mirror when you see yourself from head to toe? (The distance is not important, just so you are close enough to see yourself in the mirror.) Try looking at yourself up close and then move back to see if this is true farther away.

- **Pool Ball Reflection!**

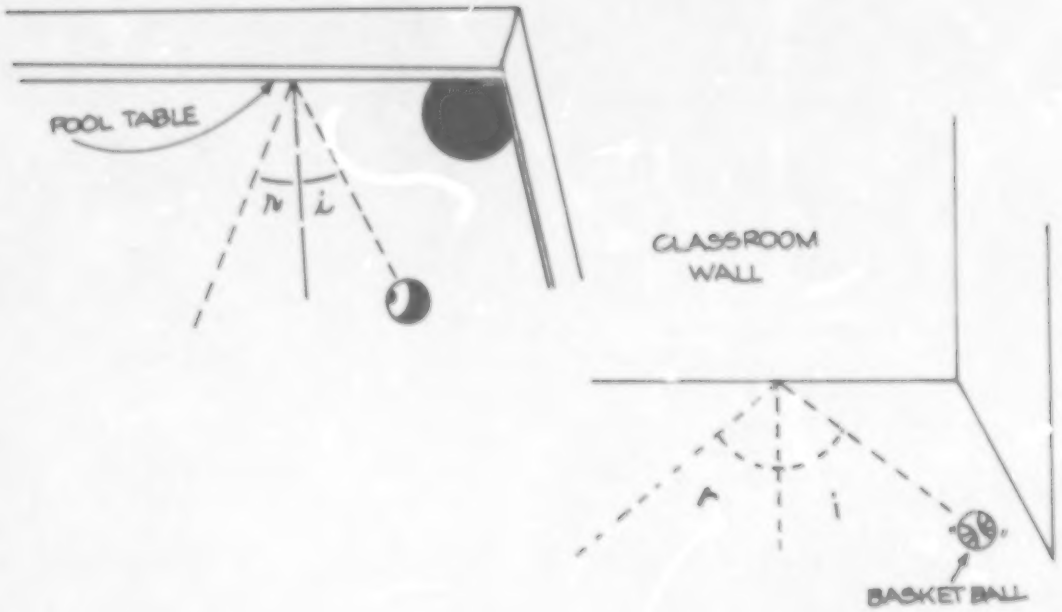
The pool ball bouncing off the side of the pool table follows the "Law of Reflection" just as light.

Angle of Incidence = Angle of reflection

$\angle i = \angle r$

Demonstrate this by rolling a basketball on the floor so that it hits the wall at an angle and is bounced off. Measure the angle it entered and the angle it bounced off the wall by marking the path of the basketball on the floor with a piece of chalk. Now draw a line perpendicular to the wall at the place where the ball hit the wall. Measure the angle from the perpendicular line to the path of the ball. This is the angle of incidence. Now measure the angle from the perpendicular to the path of the ball as it bounced off the wall. This is the angle of reflection. Are these angles the same? (Yes) When you talk about light you use the term reflection instead of bouncing. Try rolling the ball at several different angles. The same thing happens when you shoot pool. The ball is reflected off the board at the same angle it enters. Now apply this to tennis, racketball, and handball.

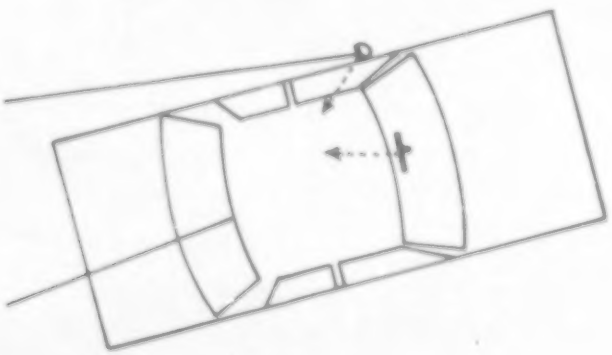
This activity can also be demonstrated on an overhead projector by using a small ball and a barrier.



- **Using the Car Side View Mirror!**

Keep in mind the First Law of Reflection, which says that the angle of incidence is equal to the angle of reflection. Apply this law to the side view mirror of the family car. Ask the students when they go home to sit in the driver's seat and adjust the mirror so they can see an object along side the back of the car. The angle of incidence is equal to the angle of reflection. The only difference is that you are closer to the mirror than the object. Now apply this law to the rear view mirror of the car.

Does this same law apply to the angle the ball goes when you hit it with a tennis racket? (Yes) Does it apply to a pool ball hitting the backboard? (Yes) Does it apply to a racket ball when the ball bounces off the wall of the court? (Yes) Can you think of other ways this law can be applied?



• **The Barber Shop Effect with Mirrors!**

You'll need a pair of mirrors taped together. Any size will do, from a pocketbook mirror to an 8" X 10". Once you have them taped together, place them on the table at right angles to each other. Place an object in between the two mirrors. How many images do you see? (3) Count the number of images. Now change the angle between the mirrors.

This is the formula for determining the number of images.

$$\text{Number of Images} = \frac{360^\circ}{\text{Angle between the two mirrors}} - 1$$

Example: $\text{Number of Images} = \frac{360^\circ}{90^\circ} - 1 = 3$

Substitute several angles in the formula such as 30°, 60°, and 180°. How many images do you see in each case?

Now try zero degrees. Separate the mirrors and place them facing each other several centimeters apart. Put an object in between the mirrors. The mirrors are now parallel. How many images do you see?

$$\text{Number of Images} = \frac{360^\circ}{0^\circ} - 1 = \text{Infinite number}$$

The infinite number of images is the "Barber Shop Effect" that is produced when mirrors are placed facing each other on opposite walls.

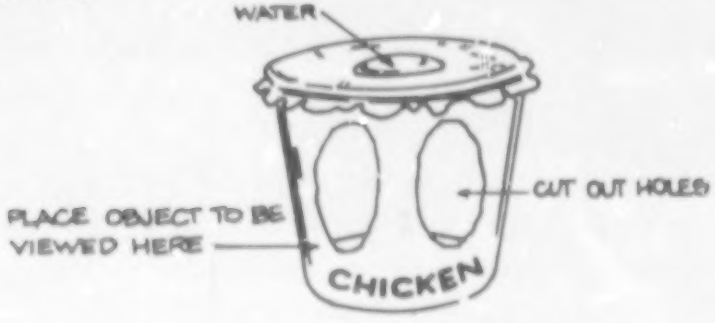
Have your students look at the effects of mirrors in the new malls. Usually mirrors are placed to enhance the merchandise and make it look like there is a greater volume thereby improving sales.

• **How Can You Bend Light?**

What happens when you put a pencil in a glass of water and look at it from the side? Does it look broken? This is called refraction. What you see is the effect of light traveling at different speeds through air and water just as sound travels through matter at different rates.

• **Water Lenses!**

Light is bent when it goes through lenses of different thicknesses. A water lens can be made with a Kentucky Fried Chicken bucket. Cut four large holes in the side; then carefully cover the top with a piece of plastic wrap, securing it with a rubber band. Pour 250 to 350 ml of water on the plastic wrap. Now put something like a twig or insect in the bottom of the bucket. Does it magnify the twig or insect? You have just made a water lens.



Make another water lens with a loop of wire. Bend the wire so that it will just hold a drop of water. Dip it in the water and hold it very close to a printed page. Does it magnify?

• **Quality Choice!**

Make a water lens by filling a spice bottle full of water. Now hold the spice bottle about 5 or 6 centimeters from the words:

QUALITY CHOICE

What happened to the word QUALITY? What has happened to the word CHOICE? Why is there a difference? (Some letters look the same when they are upside down) How many other words can you come up with that will act the same way as CHOICE?

- **Make an Ice Lens**

You'll need a refrigerator, some boiled or distilled water, and an old egg carton. Place a small amount of boiled or distilled water in the egg carton. Try different amounts of water in each section. Allow the water to freeze in the freezer. The trick is to leave it in the freezer only until the water freezes. You want the frozen water to remain clear, not cloudy as it usually is in ice trays.

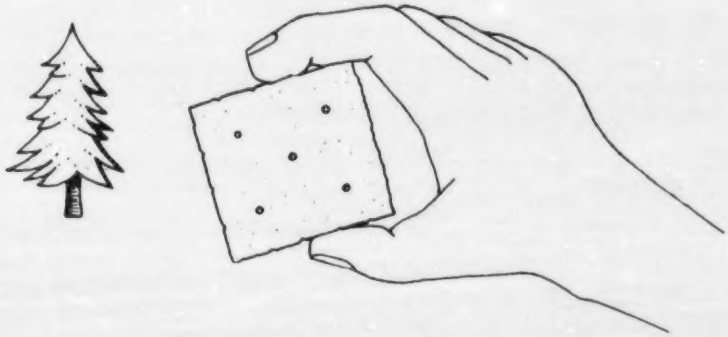
Once the water is frozen, use these pieces of ice as magnifying lenses to examine different objects. You have made a convex lens. A lens is usually made from glass or plastic. The light rays are bent or refracted as they go through the lens, making objects appear larger.

- **Soda Cracker Lens!**

Find out which students in the class wear glasses because they are nearsighted. If they have trouble seeing at a distance yet can see up close, they are probably wearing glasses to correct nearsightedness. The soda cracker lens will help them when they lose their glasses or leave them at home. Have them demonstrate this activity by taking off their glasses and holding a soda cracker close to one eye. This should be about two or three centimeters from the eye. Have them look through the hole at an object that is far away. Move the soda cracker back and forth until they see a clear image.

Why does this work? When you cannot see an object at a distance, you are nearsighted. That means your eyeball is not the right shape. It has become elongated. The light rays do not focus on the retina; therefore, you see a fuzzy picture of a distant object. By using the soda cracker lens, you are eliminating all the light rays except the ones that are focused on the retina of your eye. If you don't happen to have a soda cracker, try using a hole in a piece of paper.

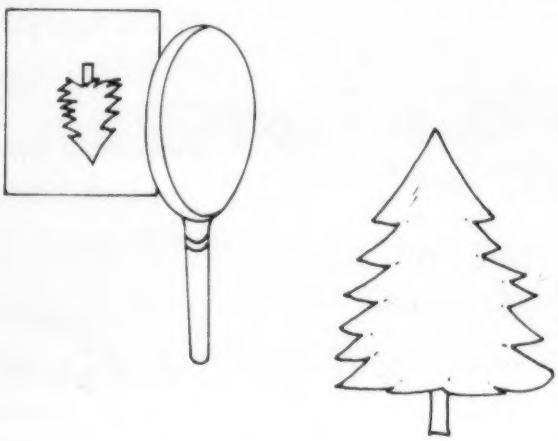
Ask someone who wears bifocals to try this activity, as it will work with a person that is farsighted, too. Be sure the person removes his glasses before looking at something up close.



- **Imaging with Lenses!**

You'll need several lenses and a piece of typing paper for imaging. Stand about 5 meters from a window with the lights off in the room. Hold one of the lenses facing the window with one hand while the other hand is holding the paper in back of the lens. Adjust the lens back and forth until you have an image of the outside on the paper. Color shows up well so aim the lens at a brightly colored car or brick building. Try imaging with the other lenses.

A quick measurement can be made of the focal length for each of the lenses, as the focal length is within 1mm of the distance from the lens to the paper. Compare the thickness of the lens to the focal length. Is the image erect or inverted (upside-down)? (The image is inverted.) Is the image on the paper larger or smaller than the object. (Smaller) Is the image real or virtual? (The image is real when it is made up of actual light rays.) Remember, optically, an eye acts like the lens in a camera with the image inverted even though objects appear erect to you. The same convex lens is found in magnifying lenses, refracting telescopes, microscopes, binoculars, and in your eyes.

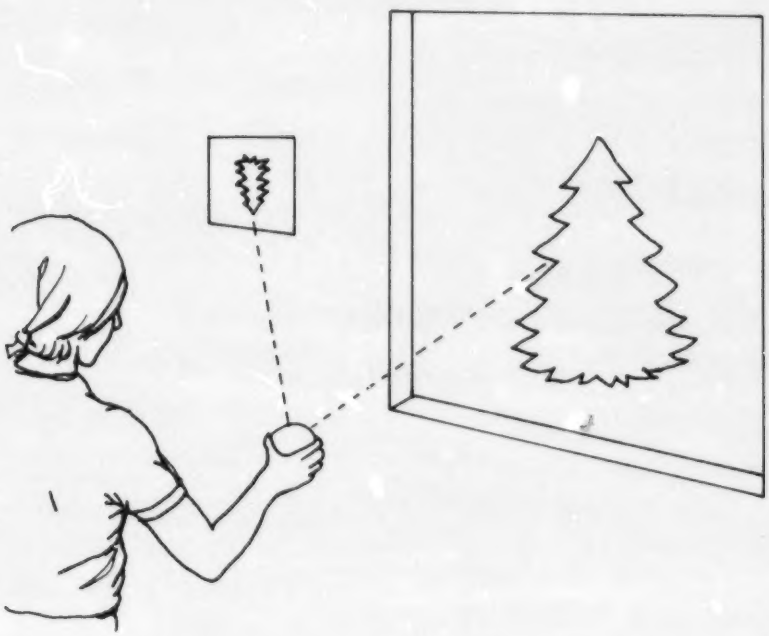


- **Projecting Images with a Cosmetic Mirror!**

For this experiment you will need a cosmetic (Make-up) mirror. A cosmetic mirror curves in at the middle. This is why it is called a concave mirror (It "caves in" at the middle.)

Demonstrate this activity by standing near a window in a darkened room. Allow the light to be reflected from the outside onto a piece of paper that you have attached to the wall next to the window. Move the mirror back and forth until the image is sharp and clear.

What are the properties of the image? Is the image erect or inverted? (Inverted) Is the image larger or smaller than the object? (Smaller) Is the image real or virtual? (Real) How do the properties of the concave mirror compare to a convex lens? (These properties are the same for both a concave mirror and a convex lens.)



- **Dispersion of Light with a Prism!**

The refraction of light can be demonstrated by using a 60 degree prism. Take the students outside when the sun is shining. Slowly rotate the prism so that the sun light can pass through the prism. Then look for the spectrum. What are the sequences of colors that you see? Often these are called Roy G. Biv colors so the students can remember the order these colors appear.

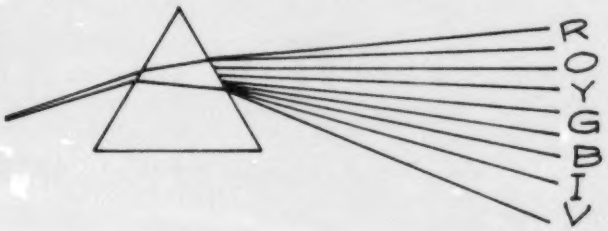
R	Red
O	Orange
Y	Yellow
G	Green
B	Blue
I	Indigo
V	Violet

His initials are the primary colors of the prismatic system.

R	Red
G	Green
B	Blue

Blue is the shortest wave length, while red is the longest. (Even though violet appears at the end of the acronym, Roy G. Biv, it is not considered a color in the spectrum. Blue is the shortest color in the visible spectrum.)

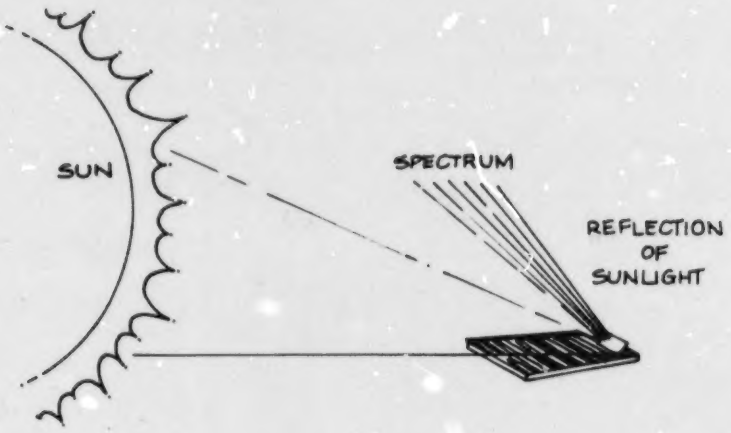
What is the best way to describe light dispersion through a prism as waves or particles? (As waves)



- **Make an H_20 Prism!**

If you don't have a prism, you can make one with a mirror, a shallow pan of H_20, and the sunlight. Fill a shallow pan about half full of H_20. Set the pan in the sunlight. With the mirror in the water, adjust it until the sunlight goes through the water and hits the mirror. This refracts the light onto a piece of paper. You will have to keep the water and the mirror very still.

Usually you think of a prism that is made out of glass. However, H_20 has the same effect. Water refracts the light rays just the same way as glass. As the sunlight passes through the H_20 prism, it separates into different wavelengths. Blue is made up of shorter wavelengths than red. Thus the color at one end of the spectrum is blue, and the color on the other end of the spectrum is red. Have the students identify the Roy G. Biv colors.



- **Interference Patterns Between Your Fingers!**

Have the students hold their hand up to a light so that they can see between two of their fingers. Now as they focus their eyes on the slit between their fingers, have them move their hand back and forth until they see dark and light interference patterns between their fingers. Are these interference patterns best explained by thinking of light as waves or as particles? (As waves)

- **Interference Patterns Through Cloth!**

To illustrate interference patterns, obtain a piece of sheer curtain material or other fabric that allows light to pass through and has a fairly large distance between the threads. Cut this material into squares. Now rotate one piece of the fabric over the other one until interference patterns are observed. Do this on an overhead projector so that everyone in the class can see the interference patterns. How is light best explained? (By waves)

- **Polarization of Light!**

The properties of polaroid filters can be demonstrated in the classroom. A pair of polarizing filters can be obtained from a number of scientific companies. This activity should be demonstrated on an overhead projector which will enable all the class to see how light is polarized. Rotate the polarizers until all the light has been blotted out.

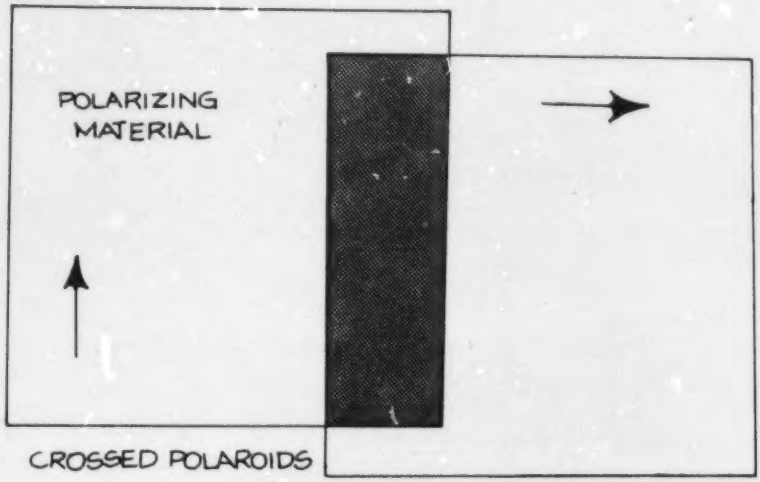
On a piece of overhead projector transparency, place several different layers of Scotch tape. Let the Scotch tape overlap in several places. Use only the cheap transparent cellulose adhesive tapes. Test this beforehand as the better tapes won't work. Now place this transparency between the polaroid filters and rotate one filter slowly. What caused the colors to appear? (Each thickness of Scotch tape caused the light to be rotated just enough so that different colors are visible.) Were the colors dependent upon the number of thicknesses of the Scotch tape? (Yes) Rotate the polaroid filters pass the 90 degrees and then back again. Did the sequence of colors change places? (Yes) This will make a more dramatic display, if you mix up the direction of the strips of scotch tape.

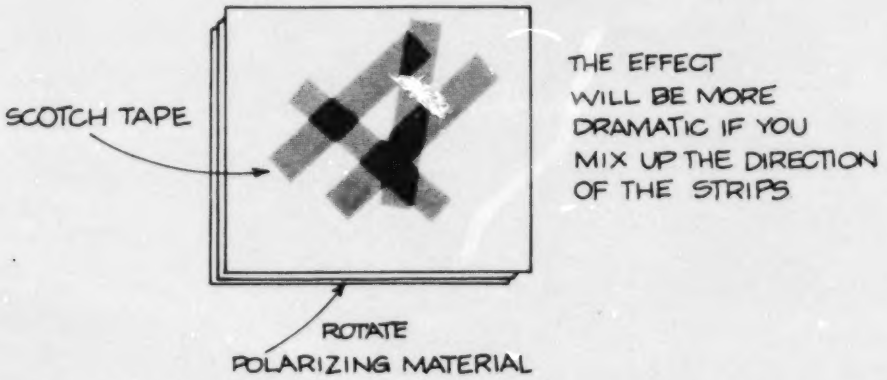
Obtain a clear plastic ruler or protractor. Place the plastic ruler between the two crossed axes of the polaroid filters. Now apply pressure to each side of the ruler. Do you see stress marks on the clear plastic ruler? (Yes) Architects often make models of objects and observe these models under stress through polaroid filters. By doing this they can locate specific areas that need to be reinforced.

Often when explaining polaroid filters, you can draw an analogy between polarizing material and venetian blinds found in many schools. The long slim molecules that make up the polarizing material allow only certain light waves to pass through. If you had a rope and were sending a wave through the blinds on that rope, only the correct polarization would be allowed to pass through. Now if you closed the venetian blinds and put a pair at right angles to each other, very little light would be allowed to go through. This is just like the polaroid filters. As you approach 90 degrees while rotating two polaroid filters, very little light if any is allowed to go through.

Polaroid sunglasses can also be used. Either buy two pairs or break one inexpensive pair into two pieces at the nose bridge. Look at glare on a shiny car or some other metal through one of the polaroid filters. What happened to the glare? (One polaroid lens will filter out the glare.) This is why you use polaroid sunglasses.

Polarization of light can best be explained if light is considered as a wave. Why is this? (If you explain light by using the particle theory, then the particles do not have any preferred polarization and would ignore the polaroid filter. However by explaining it as waves, then certain polarizations of light can go through the polarizing material as it is rotated.)


POLARIZING
MATERIAL
CROSSED POLAROIDS


SCOTCH TAPE
THE EFFECT
WILL BE MORE
DRAMATIC IF YOU
MIX UP THE DIRECTION
OF THE STRIPS
ROTATE
POLARIZING MATERIAL

APPLICATIONS OF WAVE MOTION, SOUND, AND LIGHT CONCEPTS

The behavior of sound and light has been demonstrated through mechanical wave motion. All of the properties of sound waves can definitely fit into a wave model. However, this is not true of light. Several of the properties of light can be explained better with a wave model than as a particle. Yet other properties were explained best with the particle model. Take each property of light that the students have seen demonstrated and determine if this can best be explained by a wave or particle. Some of these properties are straight line motion, reflection, refraction, interference patterns, and polarization. Is light a wave or a particle? How has this dilemma been resolved? The dual nature of light has been accepted. A particle of light is called a photon. Each photon consists of tiny packets of energy which are dependent upon the frequency of the light wave. The wave packet theory was proposed as a means of explaining the interaction between radiation and matter. The quantity of energy carried by each photon is called a quantum. This is now referred to as the quantum theory.

By applying the principles of light to laser technology, students will realize the importance of recent research. If possible, the students should see a laser demonstrated. If your school does not have one, plan a visit to a nearby college. Most colleges or universities have faculty members that will open up their facilities to students and demonstrate laser principles. A laser can be used to demonstrate reflection; refraction; interference; polarization; diverging light beams; diffraction of single, double, and multiple slits; holography; and beam splitting. It can also be used to measure the speed of light.

Have the students investigate the many uses of lasers such as:

Eye internal surgery,

Product code scanner in the supermarket,

Transferring photographs and maps to printing plates,

Sensing devices that detect molecules of pesticides, nerve gases, and power-plant pollutions,

Surveying tool to line up tunnels and ditches,

Cutting steel saw blades,

Detecting fingerprints,

Using videodisc technology in teaching and entertainment,
Holography, and

Solving the energy technology with nuclear fusion.

Laser technology harnesses light, one of the basic forms of energy. When mechanical energy was harnessed, the industrial revolution followed. We may be in for another kind of revolution. This time it will be through harnessing laser technology.

UNIT XII
STATIC CHARGES AND CURRENT ELECTRICITY

OBJECTIVE

The students will differentiate between the two types of charges and relate this to the discovery of current electricity.

TEACHING STRATEGIES

Most everyone has experienced static charges at one time or another. Begin by asking the students to list all of the places they have encountered static electricity. Give the students experiences in producing static charges; this will help them understand these properties. This can be done through SCOTCH TAPE CHARGES! and EXPERIMENTING WITH STATIC ELECTRICITY. CHARGING PENCIL SHARPENER SHAVINGS, CHARGED 2 X 4, and CAN WATER BE CHARGED? will permit the students to see how unusual objects such as wood and water can also become charged. The activity, IS THERE MORE THAN ONE TYPE OF STATIC CHARGE?, will demonstrate to the students how Benjamin Franklin realized that there were two types of charges. CHARGING BY INDUCTION will illustrate how objects can be charged without coming in direct contact.

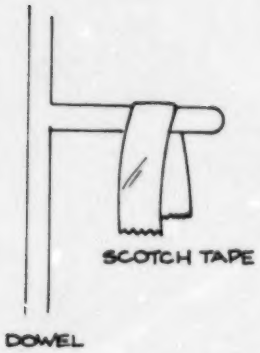
Even though static charges have been known and could be produced, no one knew just how to control or make use of these charges until Alessandro Volta made a simple cell. You can quickly lead into the discovery of batteries. In WHAT'S IN A BATTERY? will give the students experience in making a simple cell. This can be related to the function and dependence of batteries in automobiles, toys, portable tape decks, and radios. By doing the activity SEPARATE THE CONDUCTORS FROM THE INSULATORS, the students will learn which materials will hold a static charge and be conductors of electricity and which will not.

ACTIVITIES

- **Scotch Tape Charges**

Transparent tape can be electrically charged. Pull off several pieces of scotch tape about 15 centimeters long and stick them on the top of the desk. Now peel one of these pieces off of the desk. See if the tape is charged by placing it close to several small pieces of paper. Did the paper jump up at the tape? Which is charged, the tape or the paper?

What effect do two charged objects have on each other? Charge the tape by sticking it to the desk and then peeling it off. Suspend this piece from a wooden dowel that is attached to a ring stand. Put the sticky side away from you. Charge a second piece of tape by peeling it off the table. Bring it close to the piece suspended from the dowel being careful to keep the two sticky sides away from each other. What happened? Try other objets such as pieces of paper, cloth, and hair to see if these are attracted by the charged tape. Look for other materials such as plastic wrap that will retain an excess of electrons and become charged.

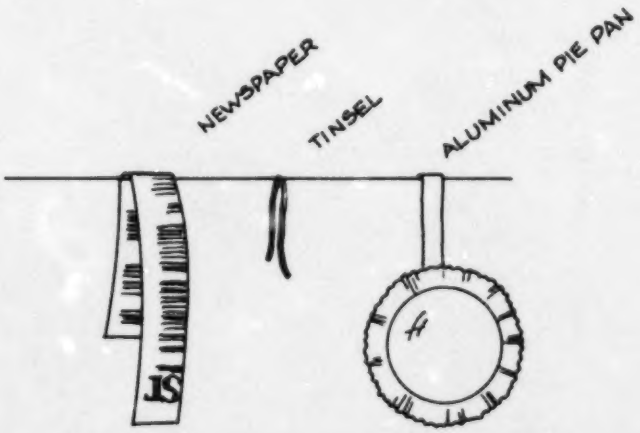


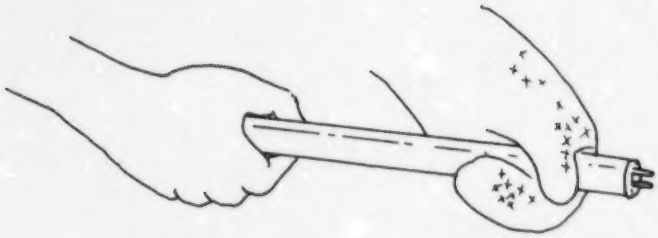
- **Experimenting with Static Electricity**

There are so many daily encounters with static charges that students should be given an opportunity to investigate some of these properties. You'll need a piece of newspaper, Christmas tree tinsel, aluminum pie pan, spool of cotton thread, fluorescent light bulb, rubber rod, and a piece of wool.

First hang a strip of newspaper over a piece of cotton thread. Then hang a piece of Christmas tree tinsel over the cotton thread and suspend an aluminum pie pan by scotch tape from the thread. After rubbing the rubber rod vigorously with the wool cloth, bring it close to the items that you have assembled on the thread. What happened? Which items were attracted by the charge on the rubber rod? Try some other items such as different types of cloth, typing paper, and hair.

Rub the wool cloth against a fluorescent light bulb vigorously. Make sure that the light bulb is good. What happened? If you cannot see the bulb glow, try this in a dark closet or darkened room. Why did the fluorescent light bulb glow? (When you rubbed the bulb with the wool cloth, extra electrons collected on the bulb's surface and excited the electrons inside the bulb causing these electrons to jump up to higher electron levels. As the electrons dropped back down, a small amount of energy was given off in the form of light.)



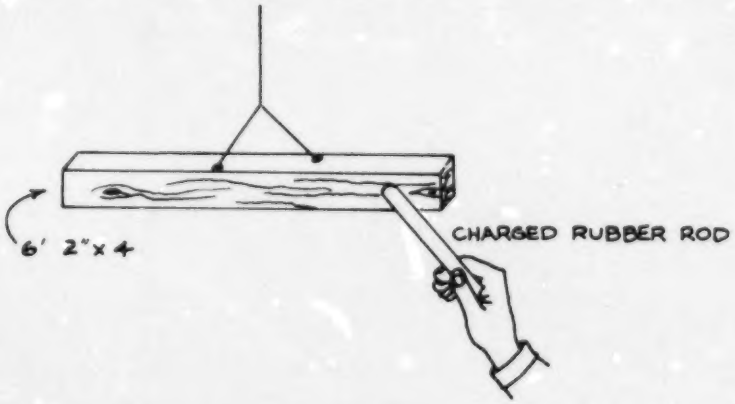


- **Charging Pencil Sharpener Shavings**

You'll need a plastic milk jug, a few shavings from the pencil sharpener, and a piece of wool. Cut a piece of plastic about 15 cm long and 4-5 cm in width from the milk jug. Make certain one end is pointed. Now, vigorously rub the pointed end of the plastic with the wool cloth. Bring it close to the pencil sharpener shavings. What happens? Which part of the pencil shavings is most attracted to the charged plastic?

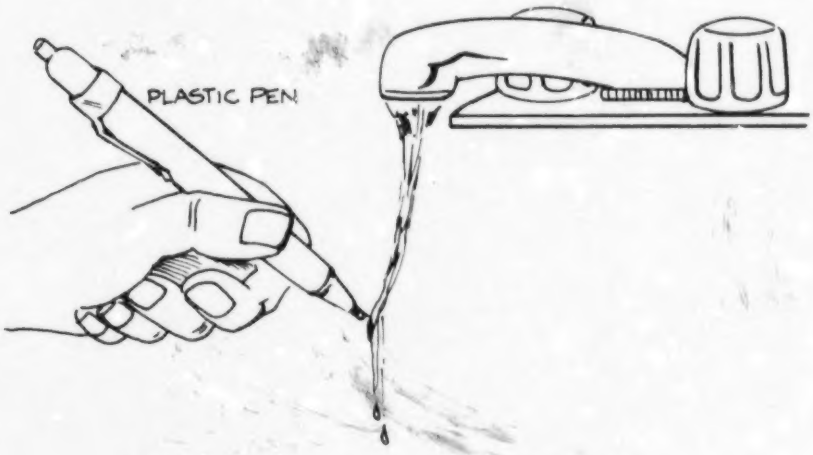
- **Charged 2 X 4**

You'll need a hard rubber rod, a piece of wool, and a 6 foot 2" by 4" for this demonstration. Suspend a large 2" by 4" (about 6' long) so that it can swing freely. Charge the rubber rod with a piece of wool. The 2" by 4" can be rotated with the attraction of the charged rubber rod. Another version of this activity is to balance the 2" by 4" on a watch glass and then use the charged rubber rod to attract it. Is the 2" by 4" charged?



- **Can Water Be Charged?**

You can attract a small stream of water by using static electricity. Rub a plastic pen, such as a ball-point pen, vigorously with a wool cloth. Now hold the point of the pen close to a very thin stream of water. This may take several trials. You may need to try several different types of pens. Try a plastic comb. Try other pointed objects. Which worked the best? If you can't find a pen or comb that works, then purchase a rubber rod. Why is the water attracted with a charge? (The water molecule has a positive end and a negative end. As you bring the charged pen or rubber rod close to the small stream of water, extra electrons on the charged object attract the positive end of the water molecule.)

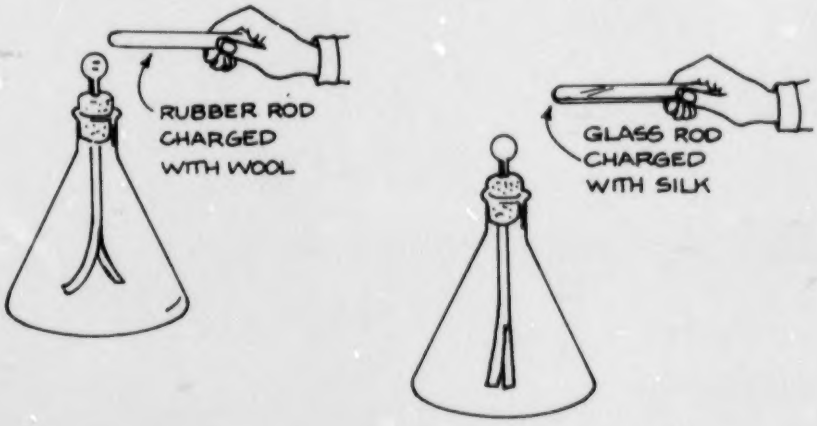


- **Is There More Than One Type of Static Charge?**

A glass rod (or lucite) and a piece of silk have something in common yet are very different from a rubber rod and a piece of wool. Let's see what it is! Several things will be needed in order to figure out the difference between the charges. You'll need an electroscope, a glass or lucite rod, rubber rod, and pieces of silk and wool.

Vigorously rub the glass (lucite) rod with the silk cloth. Now bring the glass rod close to the electroscope and touch the collector plate or ball on the top the electroscope. Were the electroscope leaves deflected? Now charge the rubber rod with the wool cloth and touch it to the collector plate. How were the leaves affected this time?

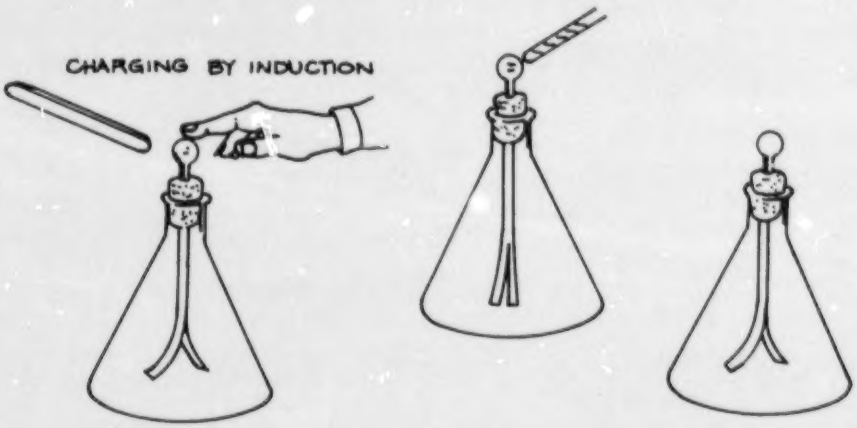
In Benjamin Franklin's day, wool and amber (this was before rubber had been invented by Goodyear) were considered common as wool came from an animal and amber came from the ground. The charges produced by these common things, Franklin called "negative." Silk and glass (crystal) were considered a sign of elegance, for silk came from the orient and crystal was expensive. Only the wealthy could afford either of these items. Because of their elegance, Benjamin Franklin assigned the charges made by these items as "positive." This should help the students remember the difference between the common materials of wool and rubber that produced the negative charge, -, and the elegant positive charges, +, produced by glass and silk.



- **Charging by Induction**

An electroscope can also be used to demonstrate the difference between the two charges. Charge an electroscope by induction. This can be done by charging a rubber rod with a piece of wool. Now bring the charged rubber rod close to the collector plate of the electroscope with your right hand. Do not touch the plate with the charged rubber rod. With your left hand, draw off all of the excess electrons by touching the collector plate. Now withdraw your left hand and the charged rubber rod. The leaves of the electroscope should fly open. Follow this procedure several times until you have a good charge on the electroscope.

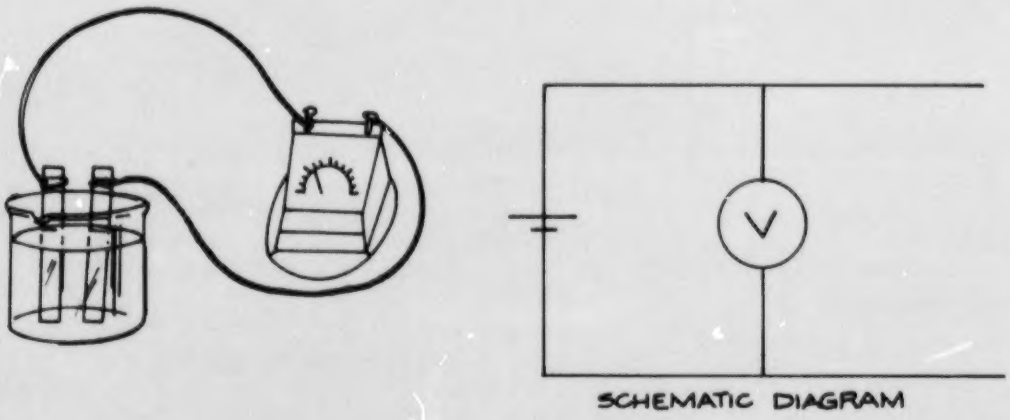
Next, charge the glass (lucite) rod with the silk cloth. Bring it close to the collector plate. What happened? (The leaves on the electroscope should collapse when the opposite charge comes close to the charged electroscope.)



- **What Is in a Battery?**

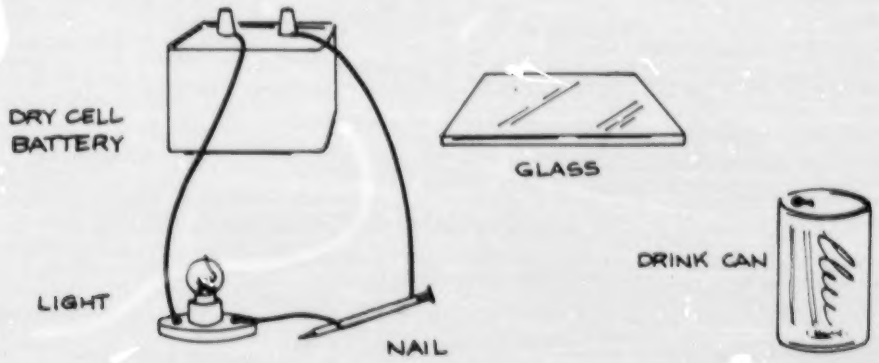
A very simple cell can be made with dilute sulfuric acid, zinc and copper strips, a few centimeters of copper wire, a battery jar (or large peanut butter jar), and a voltmeter. Hook up the copper wires to the zinc and copper strips as illustrated. Draw a circuit diagram on the chalkboard. Compare this battery to a lead-acid automobile storage battery. Which acid is used in the automobile storage battery? (Sulfuric acid) What material is used for the poles? (Lead and lead oxide)

Find a used large dry cell battery. Get someone in the shop to saw through the cell vertically. Identify the carbon rod, chemical paste, zinc jacket, and + and - poles with the screw posts. Investigate a used "D" battery or a rechargeable cell in the same way.



- **Separate the Conductors from the Insulators**

Gather an assortment of items to test for electrical conductivity. Use a dry cell battery or a dc power pack, two probes, and a small socket and bulb. Assemble these items so that the current must go through the materials in order for the bulb to light up. Test such items as glass, sand, cotton thread and cloth, synthetic materials of all kinds, graphite from a "lead" pencil, aluminum and plastic wrap, wood, cardboard, chalk, wooden dowel, paper, plastic bread wrapper or milk jug, nail, copper penny, and aluminum drink can.



APPLICATIONS AND IMPLEMENTATION OF STATIC CHARGES AND CURRENT ELECTRICITY

Whenever objects have an imbalance of electrons and protons, a charge is formed. If something has more electrons, it becomes negatively charged. If it has more protons than electrons, it becomes positively charged. Certain materials tend to gain electrons while others lose electrons. By giving the students experiences with static charges, they will become aware of the variety of materials as well and the difference in charges found daily all around them. By comparing the two types of charges outlined by Benjamin Franklin, the students will quickly see how charges can be produced.

Relate static charges to the experiences that students have like sliding across the seat of an automobile, seeing sparks when rubbing a cat at night, combing their hair just after it has been washed, scuffing their feet across a wool rug and touching a metal door knob, or plastic wrap clinging to itself as you tear it from the roll. What happens when you take synthetic clothes off? What happens when you move the synthetic thermal blankets on your bed? Do you hear a snap of electricity? If it's dark, do you see a flash of light? Why do some materials always seem to have a static charge and others do not? Could it be the fabric? Are synthetic materials like acetate fabrics conductors or insulators? (Conductors) Is cotton a conductor or insulator? (Insulator) What is the purpose of using a water softener after you wash your clothes? (It eliminates static charges.) Why do you use a hair conditioner after washing your hair? (Eliminates static charges)

Lightning is a static charge with a much greater magnitude than you can generate by rubbing a rubber rod with a piece of wool. Benjamin Franklin proved by his famous kite and key experiment that lightning was a huge static charge. Wind in a thunderstorm pushes around large masses of rain and air. These moving masses tend to gain and lose electrons thereby building up positive or negative charges. As these charges move close to the earth, an opposite charge is induced on the ground. The attraction between the two charges becomes so great that finally there is a discharge of electrons which is the lightning that you see. How do people protect themselves from lightning striking their houses? (Install lightning rods on the roof that are grounded.) Has the lightning ever knocked out your TV or hot water heater? Check to see how the TV antenna is grounded at your house. Also contact the local radio and TV stations as well as power and telephone companies to see what kind of lightning protectors they use.

Although static charges have been understood for some time, little practical use has been made of this knowledge. However, one major use of this concept has been developed as a way of filtering the smoke and dust from furnaces. By charging the particles and then placing a collector plate in a position so that it attracts smoke and dust before it leaves the stack, the particulates are removed from the exhaust fumes. The collector plates are cleaned frequently by scraping or shaking. This type of air filter is called an electrostatic precipitator. Have the students locate several in the area.

Static electricity was known several thousand years before current electricity was produced. Even though early scientists could produce a static charge, they had very little use for it until Alessandro Volta became the first to discover a way of producing a continuous electric current. He made a simple electric cell by dipping two different metals in a solution. This is similar to the activity WHAT'S IN A BATTERY? Compare this simple voltaic cell, the lead-acid storage battery, and the dry cell. Which are the + and - poles of each cell? Which chemicals are used for the liquid or paste? What is the maximum voltage that each battery can produce? What is the purpose of a storage battery? How are these used in golf carts and electric cars? Where are batteries used for auxiliary power? (Hospitals) How is a battery recharged? Our dependence on batteries is incredible. A few of these uses are battery powered portable stereos, alarm clocks, digital watches, cameras, handicap wheel chairs, hearing aids, heart pacemakers, and pocket calculators. What are some of the other electronic devices that are used daily which require a battery?

UNIT XIII
MAGNETISM AND ELECTROMAGNETISM

OBJECTIVE

The students will recognize the relationship between magnetism and electricity and analyze how these principles have been used in electric motors and electronic equipment.

TEACHING STRATEGIES

As we move into a high tech age, an understanding of electricity is essential. These activities will help the students understand how the principles of magnetism are used to generate an electric current, run motors, and operate telephone receivers. CAN YOU MAKE A COMPASS OUT OF A MAGNET?, MAGNETISM, and WHAT IS A MAGNETIC FIELD? will give the students hands-on experiences in understanding the invisible magnetic field surrounding the earth. The activity on HOW TO STORE BAR MAGNETS adds to an understanding of magnetic properties and will make certain that the school magnets are handled properly. The students must also be able to identify magnetic properties of different materials through WHAT OBJECTS ARE MAGNETIC?

Combining the properties of magnetism and electricity can be achieved through HOW ARE MAGNETISM AND ELECTRICITY RELATED?, WHERE DO YOU FIND ELECTROMAGNETS?, and LET'S MAKE A DC VOLTMETER. All of these activites will allow the students to explore the properties of magnets and magnetism and help them to analyze how these properties are used in motors and electronic devices.

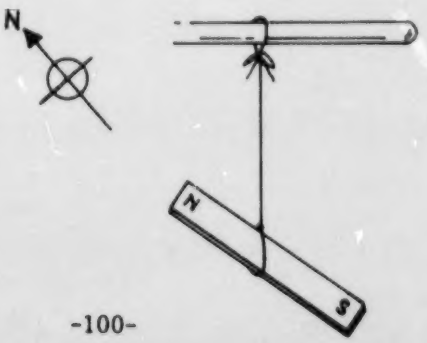
ACTIVITIES

- **Can You Make a Compass Out of a Magnet?**

You will need a bar magnet, a piece of thread and a support. Suspend a bar magnet with a piece of thread from a wooden dowel or ring stand. Allow it to hang freely without being disturbed. Does one end of the magnet point northward? Call that end the north-seeking pole and the end that points southward the south-seeking pole. You can shorten this to north and south.

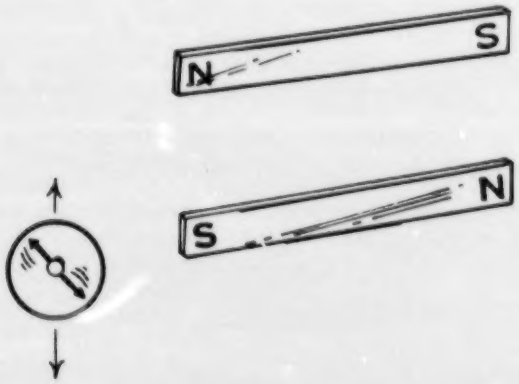
Why does one end of the magnet point northward? The earth acts like a giant magnet. If a magnet is allowed to hang freely, it will line up in the direction of earth's magnetic lines of force.

What is the difference between the magnetic North Pole and the geographic North Pole? What is magnetic declination? How does a pilot adjust for this difference?



- **Magnetism**

Arrange two bar magnets like the magnets in the illustration. Make certain the north end of one magnet is opposite the south end of the other magnet. Now put a compass close to the end of one of the magnets. Move the compass back and forth between the magnets. What happens to the needle of the compass? Does a compass act this same way when placed near other magnets? Can you explain the movement of the compass needle? (The compass needle has magnetic poles like the poles of the magnets. Unlike poles attract, north-south, and like poles repel, north-north.)



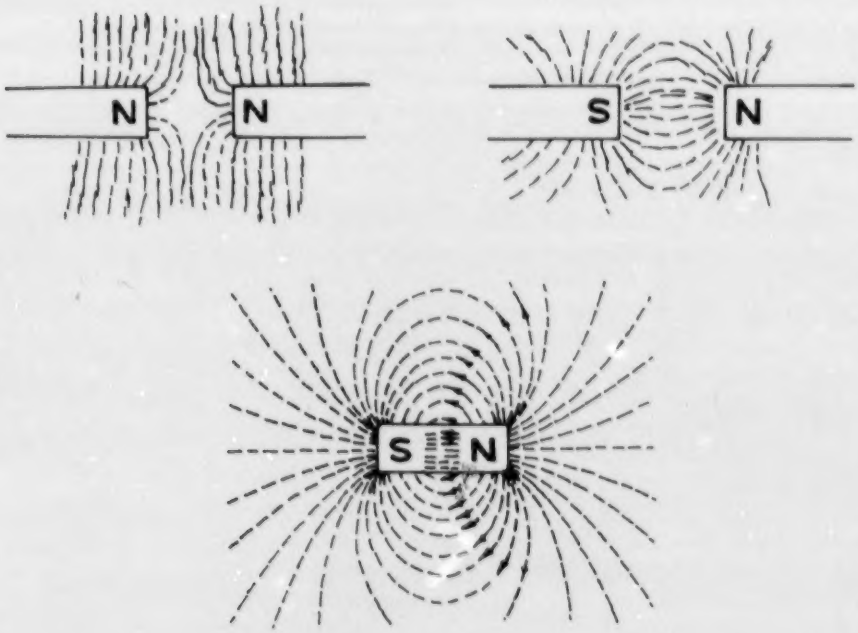
- **What Is a Magnetic Field?**

A magnetic field is invisible, yet it can be easily illustrated. You'll need a pair of bar magnets, some iron filings in an old salt shaker, piece a of acetate used for overhead projector transparency, and an overhead projector. Place the bar magnet on the overhead projector. Put the transparency on the overhead projector over the magnets and flip on the light. Now sprinkle the iron filings on the acetate that has been placed over the bar magnet. What happened to the iron filings? Did the small pieces of iron filings become aligned in the direction of the magnetic field? (Yes) Have the students draw this magnetic field on a piece of paper. Identify the north and south end of the magnet. Return the iron filings to the salt shaker.

Now place the two like ends of a pair of bar magnets about 2-3 cm apart and follow the same procedure. What is the pattern of the iron filings when two like poles are placed together? Next, see what the field is between the two unlike poles of the bar magnet? Have the students draw both of these fields. Can you look at a magnet and see the magnetic lines of force? (No)

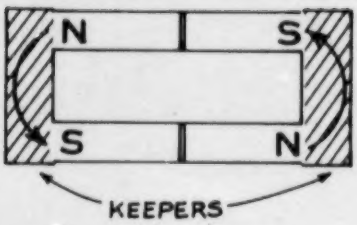
Is there a significance in the field between the two unlike poles? (Yes) What would happen if you were to cut the lines of force between these two magnets with a current carrying wire? (Electricity is produced.) Compare this to the generator of a power plant.

Do this same activity with a horseshoe magnet. Where is the strongest field? (Between the two ends of the horseshoe magnet) How are horseshoe magnets used in the old hand cranked telephones? (A current is produced by turning a coil of wire between the two poles breaking the magnetic lines of force of the magnet.) How were magnets used in an old car magneto? (Again, a current was produced by turning a coil of wire between the magnets cutting through the magnetic lines of force.)



- **How to Store Bar Magnets**

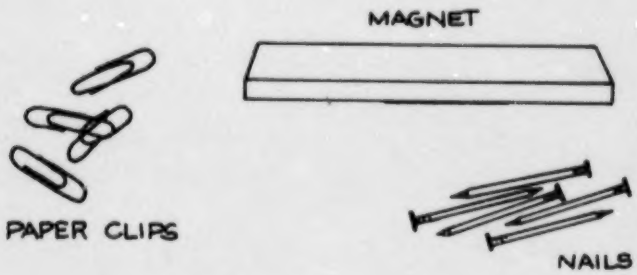
Unless you store your magnets correctly, the magnets will become very weak. Your bar magnets probably came with a small piece of metal across each end and a small amount of space between each magnet. This little piece of metal is called the "keeper." Put opposite ends of the magnets together. Then place a "keeper" across each end of the magnets. By leaving your magnets this way, the flow of magnetism will be continuously going from the north end to the south end. This will keep the magnet from becoming weak.



- **What Objects Are Magnetic?**

By looking at an object, can you tell if it is magnetic? (No) Are all metals magnetic? (No) Testing a variety of items is the best way to determine magnetic properties.

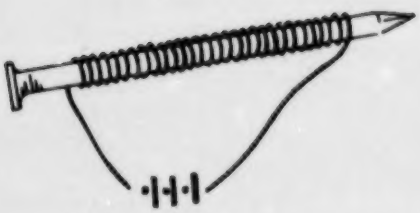
For this experiment you will need a bar magnet and several easy to find items. Try your magnet on as many objects as you can. Make certain you include a penny, lead out of a "lead pencil," aluminum foil, brass, paper clips, and nails. Make a list of all the items that you found to be magnetic.



- **How Are Magnetism and Electricity Related?**

Make an electromagnet with a nail, 3-5 meters of insulated copper wire, and a battery or dc power supply source. You'll need paper clips or small nails to determine the strength of your electromagnet. Carefully wrap the copper wire around the nail. Scrape off the ends of the copper wire so that it makes connection when you connect it to the poles of the battery. Hook up the wire to the battery poles and test your electromagnet to see if it will pick up a number of paper clips. If the electromagnet is left hooked up to the battery, what will happen to it? (The electromagnet will become hot.) What will happen to the battery if the electromagnet is left hooked up? (The battery will soon be dead.) Feel the electromagnet; did it turn warm? Heat is another form of energy.

Place a compass near each end of the electromagnet. Which is the north end? Which is the south end?



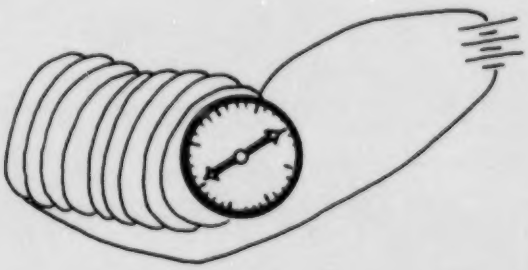
- **Where Do You Find Electromagnets?**

The St. Louis motor is one of the best ways to demonstrate how an electric motor works and the function of the electromagnets. One can be purchased from a scientific supply company. Locate the commutator, electromagnet, bar magnets, coil, and brushes. What is the function of each? Locate several old electric motors from a drill or washing machine and compare the function of each of the parts to the St. Louis motor. Where else do you find electromagnets?

- **Let's Make a dc Voltmeter**

It will take about 3-4 meters of copper wire, a dc power source, and a compass to make a simple model of a dc voltmeter. Make a coil of wire by winding it around a drink can. Scrape off each end of the wire before you connect it to the battery. Now bring the compass close to the wire. What happens? Place the compass inside the coil of wire. Now disconnect one of the wires. What happened to the compass needle? (The compass will be deflected.) Try this several times. What happens to the compass needle when you step up the current or use a larger battery?

A voltmeter that measures the amount of current that is flowing through a system works this same way. The larger the amount of electricity you use, the more the needle is deflected. As the amount of current increases, the magnetic field becomes greater and the needle of the compass rotates. How does an ammeter work? Compare this to a voltmeter.



APPLICATIONS AND IMPLEMENTATIONS OF THE RELATIONSHIPS BETWEEN MAGNETISM AND ELECTROMAGNETS

The effect of magnetic lines of force can be manifested in many ways. The students will have to do a number of these activities for them to become familiar with the field present around a magnet. Once this concept is understood, the next step is for the students to understand how electricity is generated by cutting magnetic lines of force. A visit to a power plant would reinforce this principle on a giant scale. In a hydroelectric plant, the water rotates a coil of wire through a magnetic field. In a nuclear, oil, or coal power plant the steam is used to turn the coil of wire through the magnetic field. In all cases, mechanical energy is converted to electrical energy. If you are in the magnetic field of a power plant generator, would this have an effect on your watch? (Yes)

A bicycle generator light is another example of a coil of wire being turned through a magnetic field. This time mechanical energy is converted to electrical energy and this in turn is changed into light energy.

A telephone receiver is an excellent example of how a fluctuating current is used to change the strength of an electromagnet which causes the diaphragm to vibrate. The voice patterns you hear are the result of changes in the strength of a current vibrating a diaphragm. Electrical energy is turned into sound energy through the magnetic field.

The operation of a St. Louis motor is another example of the effect of electromagnets and electricity. This time you are using the electric current to produce a magnetic field while it is rotating on a shaft. This motor converts electrical energy into mechanical energy that is used to do a variety of work. The students should now be able to analyze the function of electromagnets in the operation of generators, relays, dc and ac motors, buzzers, telephone receivers, transformers, and radios.

UNIT XIV
ELECTRONICS

OBJECTIVE

The students will demonstrate an understanding of the development of the cathode-ray tube and relate the early beginning of the tube to the present day use of the oscilloscope and color television.

TEACHING STRATEGIES

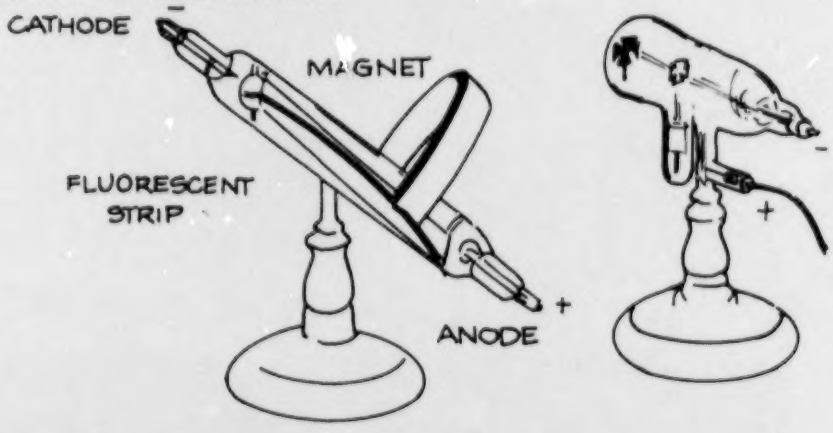
With at least one cathode-ray tube in every home, it is important that students have some idea of how this electronic device was invented and developed into the present day TV picture tube. The use of one of the forerunners, the oscilloscope, has become widely used not only in electronics but also in monitoring cardiac patients in the hospitals. It can be used to measure any oscillation (vibration) that can be changed into electricity. The students need to become familiar with the uses of oscilloscopes. (A warning to the teacher: X-rays are emitted from both of the Crooke tubes; therefore, use only a few minutes, just long enough to demonstrate the principle.)

HOW DID WE GET CATHODE-RAY TUBES? will give the students experiences in the early beginning of the TV picture tube. The next two activities, GRAPHIC REPRESENTATION OF SOUND WAVES! and WHAT ARE LISSAJOUS PATTERNS? will provide the students with practical uses of the oscilloscope by showing graphic sound wave patterns and Lissajous patterns which illustrate the addition of verticle and horizontal frequencies.

ACTIVITIES

- **How Did We Get Cathode-Ray Tubes?**

Obtain several Crooke's tubes from a scientific company. The best ones are the Maltese cross and the Crooke's tube with the fluorescent strip. You'll need an induction coil and a power source. Darken the room to demonstrate the Maltese cross tube. Start with the cross down and then swing it up. Make certain the students see the image of the cross on the end of the tube. Liken this to the cathode-ray tube. Now demonstrate Crooke's tube with the fluorescent screen. Use a magnet to show how the beam is deflected. Review the properties of the cathode ray that have been demonstrated with these devices.



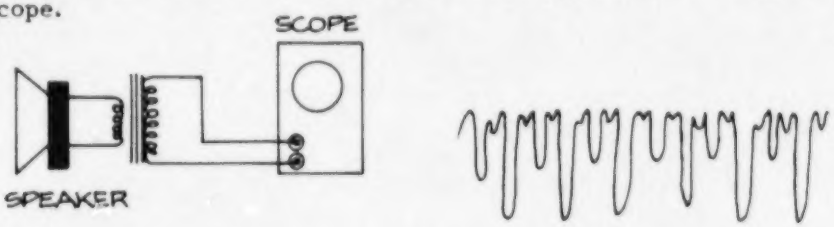
- **Graphic Representation of Sound Waves!**

You'll need an oscilloscope, a speaker, an audio generator, and a microphone. Ask the students in the band to bring their instruments to class. These will be used to demonstrate the characteristic wave patterns made by each instrument on the oscilloscope.

Hook up the oscilloscope so that the wave generator is played through the speaker and can be heard by the students. At first use the sound frequencies that are audible. Compare the different frequencies to the pattern made on the oscilloscope. Now run the audio generator up to the frequencies that are not audible to the human ear. The students will be able to see the wave patterns without hearing the high frequencies.

Hook up the microphone to the speaker and then to the oscilloscope. Try several distinct sounds such as "or" and the vowel sounds. Notice the characteristic patterns formed by these sounds. Now compare different student voice patterns. Howard Hughes was reported to have phoned from a foreign country. Nobody knew if it was the real Howard Hughes, so they compared the oscillograms that had been made previously of his voice to the voice pattern made of the phone conversation. Sure enough they verified that it was the real Howard Hughes.

Have students play single notes on different instruments into the microphone attached to the oscilloscope. Notice the characteristic wave pattern for a trumpet. What is the wave pattern for a trombone? What is the characteristic pattern for a flute? Have the students draw these patterns and compare it to a diagram found on the oscilloscope.



- **What Are Lissajous Patterns?**

Besides an oscilloscope you'll need a power source for the known frequency and an audio generator for the unknown frequency to set up a display of Lissajous patterns. Hook up the known frequency in the vertical outlet and unknown frequency in the horizontal outlet. Now adjust the horizontal-gain controls so that the pattern height and width fill up the screen. Adjust the frequency of the audio-signal generator until the horizontal signal is the same frequency as the vertical frequency. This should appear as a diagonal line. By getting these two signals out of phase an ellipse will form and then a circle. The circle represents the two signals being out of phase 90 degrees. If a circle does not appear, the voltage on both the vertical and horizontal gain needs to be synchronized. Make the necessary adjustments.

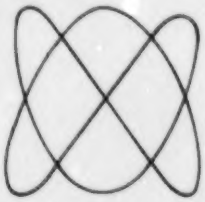
Double the horizontal frequency. This will give you a 1:2 ratio. What is the pattern that is formed? This is called the bow-tie. What are the phase variations of the bow-tie? Alter the horizontal frequency until you have the Lissajous pattern form a 2:3 frequency ratio. What does this pattern look like? Even though it is very distinctive it does not have a characteristic name. What is the pattern for the 3:4 ratio?

1:2
IN PHASE

OUT OF PHASE 30°
BOW-TIE

OUT OF PHASE 60°

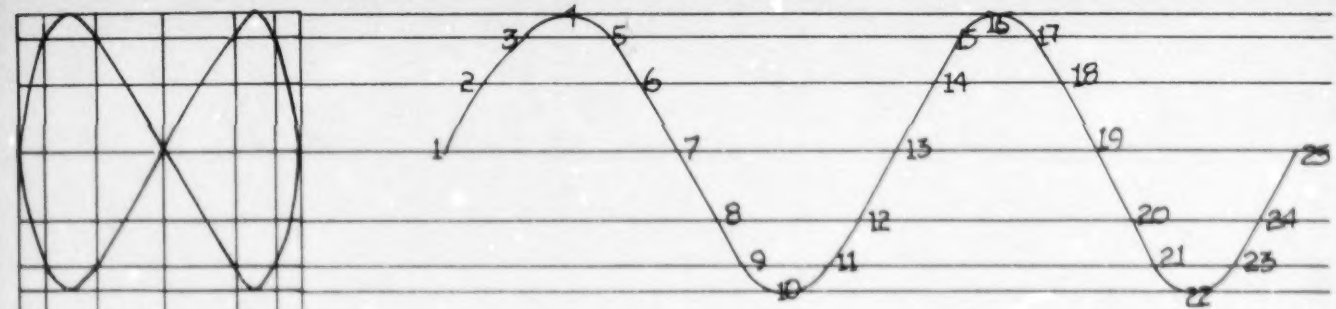
OUT OF PHASE 90°



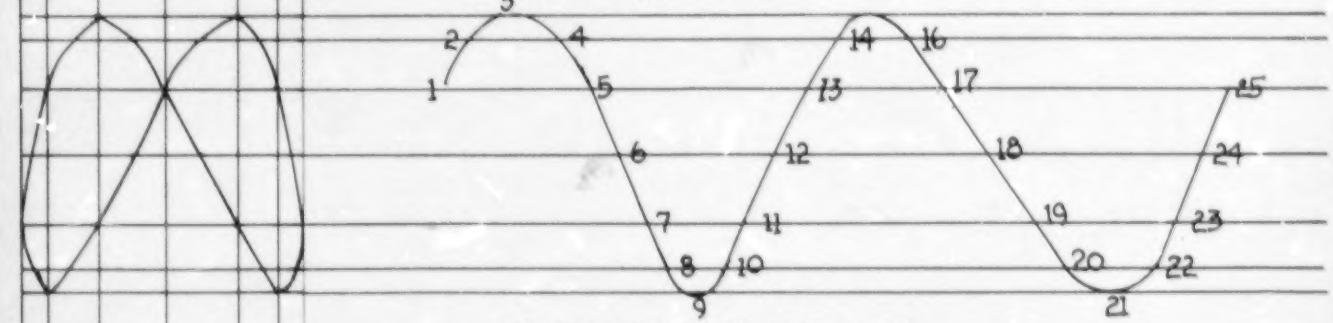
2:3 FREQUENCY RATIO

Lissajous patterns can be graphed on special paper where the vertical sine wave for the vertical frequency is plotted as a function of the horizontal sine wave which represents the horizontal frequency. Plot the points on the special graph paper for every 30 degree interval.

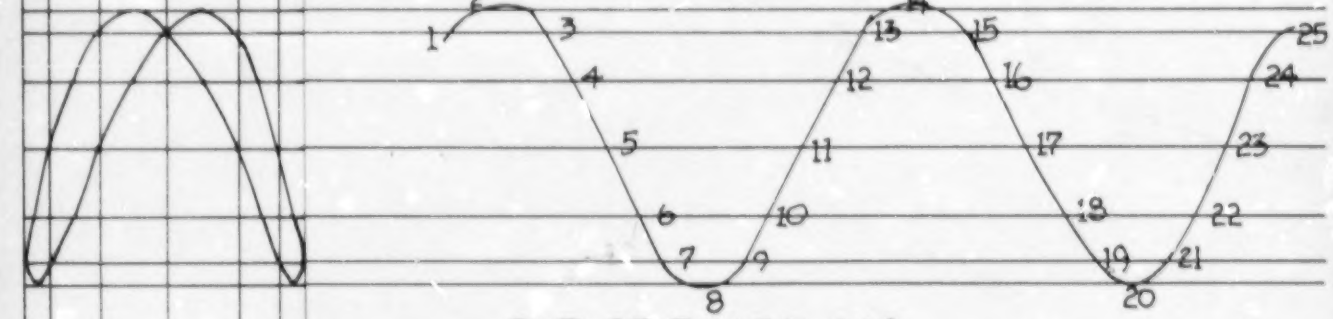
A sand pendulum can also be used to produce Lissajous patterns. Secure a sand pendulum to a ring stand. Fill the pendulum with sand. Place a piece of contrasting poster paper under the pendulum. Pull the pendulum back so that it will swing back and forth without any sideways motion. Before you turn the pendulum loose, ask the students to predict the pattern that the sand will make. If the poster paper is long enough pull it as the pendulum is swinging. What is the pattern now? (It is a sine wave.) Now pull the pendulum back so that it is allowed to swing with a sideways motion. What pattern does the sand make now? (If you adjust it right, you will get a bow-tie.) This is another example of the addition of two motions combining to form Lissajous patterns.



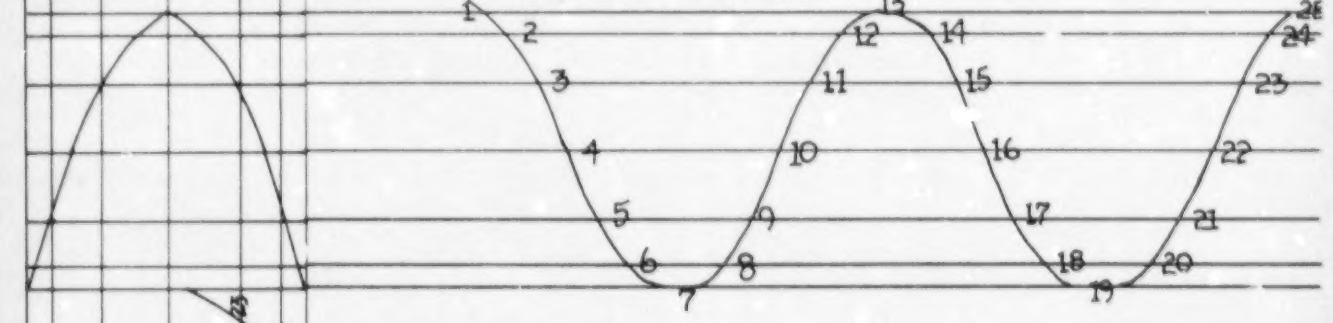
OUT OF PHASE 30°



OUT OF PHASE 60°



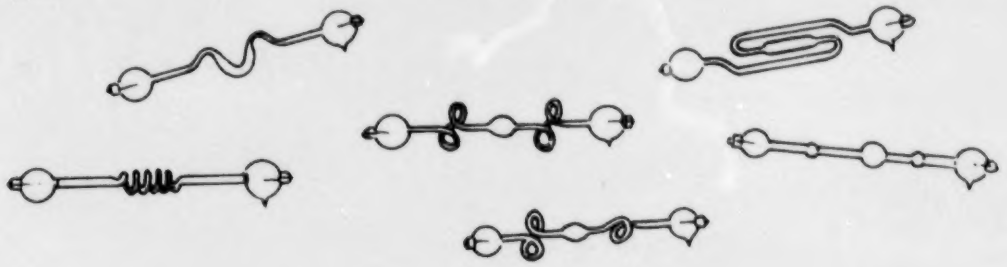
OUT OF PHASE 90°



Ratio 2:1
Phase Variation
LISSAJOUS FIGURES

APPLICATIONS AND IMPLEMENTATIONS OF ELECTRONIC PRINCIPLES

The discovery of the cathode-ray tube was the result of experiments where electricity was allowed to pass through evacuated tubes. Each tube has two poles, one called the cathode and the other called the anode. Most of the air has been evacuated from these tubes. The early electronic devices were called Geissler tubes in honor of the man who did the original experimental work. Through investigations of the properties of electric currents, Geissler concluded that there were both positively and negatively charged particles present in these tubes. The positive charges move in an opposite direction from the negative charges. Positive charges are attracted to the negative electrode of the tube, and negative charges are attracted to the positive electrode. These charged particles are called ions. When an air molecule has an extra electron it becomes a negative ion. If it loses an electron, it becomes a positive ion. When an electric force is applied by a spark coil to the electrodes in the Geissler tube, it tears out electrons from the air molecules. This results in a large number of positive ions and a large number of negative ions in the Geissler tube. These tubes were designed in all sorts of shapes in order to determine the properties of these charges.



Later Sir William Crooke gained a better understanding of the properties of electricity. He designed several tubes of different shapes that are now called Crooke's tubes. Because the flow of electrons was emitted from the cathode, this was originally called the cathode ray. It soon became evident to Crooke that the cathode ray traveled from the cathode electrode in straight lines and could not turn corners. Several tubes are available from scientific companies that make excellent demonstrations of these concepts. Crooke's tubes with the Maltese cross illustrates how the flow of electrons casts a shadow on the opposite end from the cathode.

At one time the scientists did not know if there was a difference between a cathode ray and the electromagnetic spectrum. Since light was part of the electromagnetic spectrum, J. J. Thompson demonstrated that a cathode ray could be deflected by a magnet. From this he concluded that the cathode ray was not an electromagnetic wave because light could not be deflected with a magnet. Later a fluorescent strip was placed inside the tube to show the path of the cathode ray. In 1889, Braun developed the modern cathode-ray tube. To the inside of a tube, he added charged plates that would deflect the cathode ray. In addition he placed a fluorescent screen at the end of the tube for the cathode ray to hit.

In 1921, Johnson made a new tube that we now called the cathode-ray tube. He had several sets of deflecting plates and could vary the voltage. He directed the ray to the end of the tube which contained a phosphorescent screen. When the cathode-ray tube is mounted in a case with an amplifer and various operating controls, the instrument is called an oscilloscope. This has become a useful tool in measuring currents in electronic instruments. Have the students investigate the use of testing electronic circuits in repairing radios, televisions, and amplifiers.

The television is a cathode-ray tube that has an electron beam that is as thin as pencil lead. This beam can sweep back and forth across the end of the TV tube. In just one second, 15,700 dots are made on the screen so quickly that your eye still sees the first dot as the next one appears. Radio signals are synchronized with the video signals so that you hear the audio program along with the video. Color TV has three separate electron guns producing a beam for each one of the three primary colors. These primary colors are blended together to produce all the colors similar to a photograph. Have the students look at the TV screen with a magnifyng lens to see dots formed on the screen.

UNIT XV
SPACE SCIENCE

OBJECTIVE

The students will recognize that the same principles of physical science apply to space.

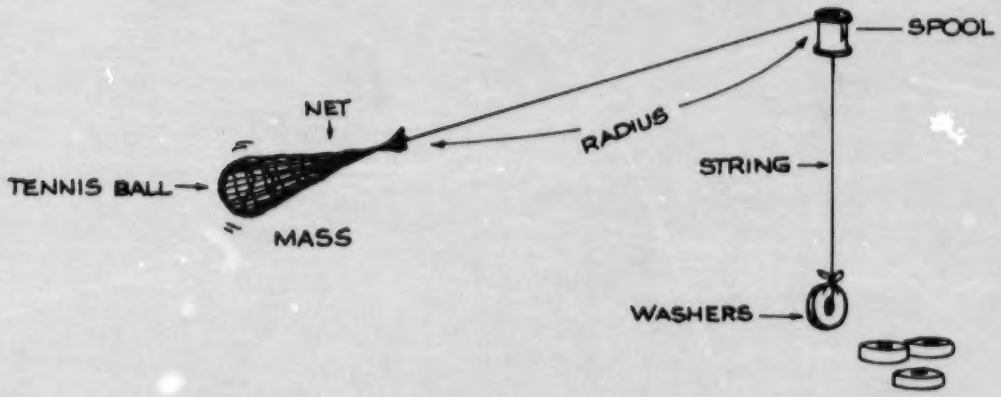
TEACHING STRATEGIES

The study of space science uses all the laws of physics just as we have used them to explain the motion of objects on the earth. Sir Isaac Newton in 1687 published Principia in which he presented his theory of motion. He really synthesized these laws from his own work along with others who had preceded him. Newton's first law is inertia that was developed by Galileo. His second law gives us the relationship of acceleration to force and inertia, while his third law relates action and reaction.

Through the activity MAKE A SATELLITE MODEL!, the students will be able to realize the variables involved in placing satellites in orbits. WHERE ARE ALL THE COMMUNICATION SATELLITES HOVERING ABOVE THE EARTH? will aid the students in understanding that all the satellites are hovering above the earth's equator about the same distance. Then with HOW DO WE MEASURE THE MASS OF OBJECTS IN SPACE?, students will be able to understand the different ways we have of measuring objects.

- **Make a Satellite Model!**

You will need an empty spool of thread, string (fishing line), a tennis ball, net from a bag of apples, and several washers. Put your model together so that it looks like the illustration.



Hold the spool in one hand and the washers in the other. Now slowly rotate the tennis ball (satellite) in a small circle over your head. The spool represents the earth. Gradually vary the speed of your satellite until the washers stay in one place. You may have to add washers. Notice the length of the string from the spool to the tennis ball. This is the radius of the orbit. Repeat this procedure, but gradually change the speed of the satellite by slowing down the motion of your arm. What is the radius of the orbit now?

Is this statement correct? When a satellite is orbiting close to the earth, it is rotating faster than when it is farther away. (Yes) Now think of the tennis ball as the planets and the spool as the sun. Does this same concept apply? Do the planets closest to the sun rotate faster than the planets farther away from the sun? (Yes) The tennis ball is the satellite, the radius of orbit is the length of the string from the spool to the tennis ball, and the force that holds the satellite in orbit is the mass of the washers.

Ask the students to determine all of the variables in this activity that can change the velocity of the orbit. (e.g. The mass of the ball, the number of washers, and the length of the string or radius can all alter the velocity of the orbit.) If you used a more massive ball, what would happen to the velocity of the tennis ball? Did you have to alter the radius of the orbit? Using the tennis ball as your satellite, add more washers. What happens to the velocity of the tennis ball? Did the radius of the orbit change? This is the formula for the forces that holds a satellite in orbit.

$$F_{\text{centripetal}} = \frac{\text{mass (velocity)}^2}{\text{radius}}$$

- **Where Are All the Communication Satellites Hovering Above the Earth?**

All of the satellites hovering above the earth for communication purposes are strategically placed the same distance from the center of the earth and above the equator. This allows radio waves to be transmitted to all parts of the world, thus providing live TV and radio coverage to all countries. In order to transmit continuous communication waves, these satellites must remain in synchronous orbit with the earth above the equator and the same distance from the earth's center. This distance that the satellites are hovering over the earth can be calculated by using two well known formulas.

The formula for centripetal force of the satellite is equated to the formula for force due to gravity between the satellite and the earth. The use of a pocket calculator will make this activity more enticing to your students.

F_C = Centripetal Force of the Satellite

$$F = \frac{M_S v^2}{r}$$

F_G = Gravitational Force between the earth and the satellite

$$F_G = \frac{GM_e M_s}{r^2}$$

M_s = Mass of the satellite

M_e = Mass of the earth = 5.96×10^{24}kg

r = Distance from the center of the earth to the center of the satellite

G = Newton's gravitational constant = 6.67×10^{-11} Nm^2/kg^2

t = Time = Period of the earth = 1 day = 24 hr

v = Velocity of the satellite

$$F_C = F_G$$

The inward centripetal force is equal to the outward centrifugal force as in the following equation.

$$\frac{\text{Centrifugal Force}}{\text{out}} = \frac{\text{Centripetal Force}}{\text{in}}$$

$$\frac{M_s v^2}{r} = \frac{GM_eM_s}{r^2}$$

Cancel the mass of the satellite in each formula

$$\text{Substitute } v = \frac{2\pi r}{t} \quad \text{for} \quad \frac{\text{distance}}{t}$$

Time = Period = 24 hours = 86,400 sec

$$\text{Time} = \frac{24 \text{ hr}}{} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 86{,}400 \text{ sec} = 8.64 \times 10^4 \text{ sec}$$

$$\frac{M_s v^2}{r} = G \frac{M_e M_s}{r^2}$$

$$v^2 = G \frac{M_e}{r}$$

Since $v = \frac{2\pi r}{T}$ and for a circular orbit we have

$$\left(\frac{2\pi r}{T}\right)^2 = G \frac{M_e}{r}$$

$$\frac{4\pi^2 r^2}{T^2} = G\frac{M_e}{r}$$

$$r^3 = G\frac{M_e T^2}{4\pi^2}$$

$$r^3 = \frac{(6.67 \times 10^{-11}\,\text{Nm/kg})(5.96 \times 10^{24}\,\text{kg})(8.64 \times 10^4\,\text{s})^2}{4(3.14)^2}$$

r = distance from the center of the earth

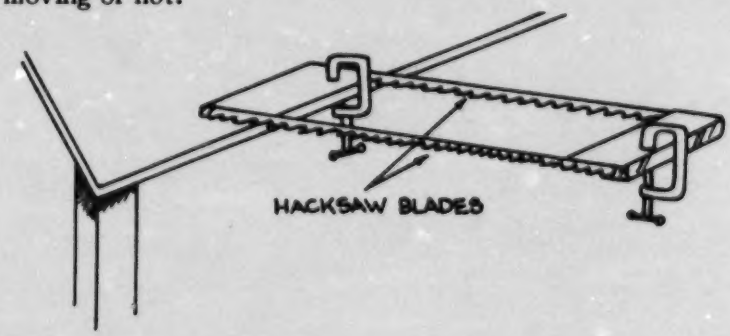
r = (4.2×10^7 m or 4.2×10^4 km)

The satellites appear to be hovering above the earth because these satellites are in synchronous orbit with the earth. These satellites have been placed the same distance from the earth directly above the equator so that they appear to be at the same spot over the earth. What is this distance? (r = 42,000 km) Is the mass of the satellite important (No! The mass of the satellite is not important. Remember you cancelled the mass of the satellite in both equations.)

When these satellites vary from their orbit above the earth's equator, boosters must be fired to get the satellites back into this position of a synchronous orbit with the earth. This enables us to send radio and TV signals from continent to continent on earth by bouncing the signals from synchronous satellites thus providing us with world wide communications.

- **How Do We Measure the Mass of Objects in Space?**

There are several ways to take the mass of an object. You can measure the mass of an object by using a spring scale, a balance pan, or by measuring an object's resistance to motion called inertia mass. Inertia was first postulated by Galileo. Later Newton included it as his first law of motion which stated that, "A body in motion remains in motion or a body at rest remains at rest unless it is acted upon by an outside force." This tendency of an object to resist motion is called inertia whether the object is moving or not.



The spring scale is used frequently. An excellent example is the bathroom scale which uses a flat spring. Take an old bathroom scale apart and find the spring. The spring scale is a common tool used in the laboratory. The term weight is used with a spring scale e.g. "I weigh 125 pounds." Spring scale measurements are dependent upon gravity. Using a bathroom scale, would your weight be slightly different at the top of "Old Smokies" than if you were at Myrtle Beach? (Yes) Would your weight be increased or decreased in the mountains? (Decreased on the top of "Old Smokies" because the pull of gravity is less. Remember you are farther from the center of the earth.) Imagine using a spring scale in space where there is no gravity. Would the spring scale be of any value? (No)

The second way to measure the mass of an object is by using a balance pan with calibrated masses. You are comparing the mass of an object to known calibrated masses. Notice the term mass is used, e.g. the mass of the chemicals is 250 grams. Would this measurement change if you were to go to the top of "Old Smokies?" (The mass would be the same.) In other words you are comparing the mass of the object to known calibrated masses. Could you use a balance pan to take the mass of an object out in space? (No! A balance pan is dependent upon gravity to pull the masses toward the earth.)

The third way to measure the mass of an object is to determine its inertia or resistance to motion. You'll need 2 hacksaw blades, 2 small wooden blocks about 4" long, some masking tape, 2 C-clamps, 5 or 6 heavy washers, and a stopwatch. Assemble the apparatus by taping a wooden block between each end of the hacksaw blades as shown in the diagram. One C-clamp is used to fasten the apparatus to a table, while the other C-clamp is used to secure the washers as these are added one by one. The washers become the masses that cause the differences in the velocity of the oscillations of the hacksaw blades.

Depending upon the students, you can use this as a demonstration by visually "eye balling" the oscillation (vibration) changes as the mass is increased. Or you can make measurements and actually take the mass of an object.

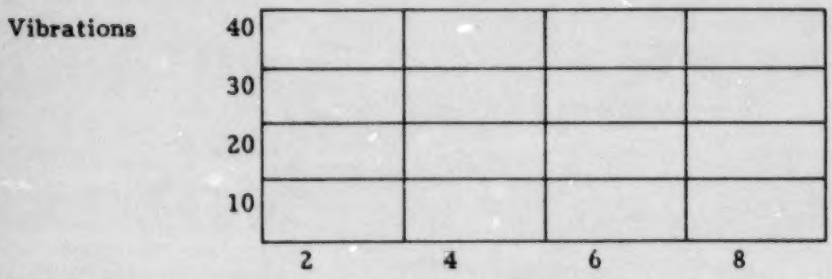
If you plan to take the mass of an object, you must calibrate the inertia balance apparatus with a set of washers. Do this by making measurements using at first 1 washer then 2 washers, until you have made measurements for each of the washer's resistance to motion while attached to the outer edge of the apparatus. Count the number of vibrations in 15 seconds after the addition of each washer. Plot this data on graph paper.

SUGGESTED DATA TABLE

DETERMINING THE INERTIA MASS

WASHERS	NUMBER OF VIBRATIONS in 15 seconds
1	
2	
3	
4	
5	
6	

GRAPH OF INERTIA MASS



Take the inertia mass of a set of keys or something that has about the same mass as the washers. Does this method depend upon gravity? (No, as long as you have the apparatus swinging horizontally.) Can you take the mass of objects in space this way? (Yes) How do the astronauts take the mass of objects in space? (Using inertia balance).

APPLICATIONS AND IMPLEMENTATION OF SPACE SCIENCE

The interesting aspect of space science is that all laws of physics apply. It is only when you approach the speed of light that classical physics cannot be used. It is then that Albert Einstein's theory of relativity takes over. Each of Newton's three laws can be applied to orbiting satellites as well as his Law of Universal Gravitation. The term inertia was hard to comprehend until we experienced situations where there was no gravity and realized that objects in space once set in orbital motion continued in their path.

When you examine closely the positioning of the communication satellites, Newton's Laws can be easily applied. An analogy can be drawn between the speed of the communication satellites and the distance these satellites are located from the earth; just as the velocity of the tennis ball depends on the radius of orbit. In order to maintain a synchronous orbit with the earth and remain in a stationary position over one point of the earth, these satellites are spaced along an extended line out from the earth's equator. Communication satellites all have the same radius of orbit, and all remain at a fixed place above the earth. This is because the satellite and the earth rotate at the same angular speed around the rotation axis of the earth. The formula for centripetal force is used for determining this orbit. These satellites have been placed at strategic locations over the earth so that people everywhere will have access to better communications.

Understanding the term inertia can be achieved through taking the inertia mass of objects and realizing that this is the way that the mass of objects must be measured in space. By these activities, it soon becomes apparent that the laws governing inertia and gravity can be applied to space science.

PHYSICAL SCIENCE: GENERAL
BEDS Code: 462
Acceptable Certification Codes: 12, 13, 15, 16

I. COURSE OBJECTIVES

This course will serve as a background for students who desire to learn practical applications of science before taking vocational courses or entering the work force upon graduation from high school. An introduction to basic physical science principles will be correlated with technical applications used in trades, industry, and health-related fields, making the course content relevant to the surroundings. It is essential that applications of physical science principles be complemented with laboratory experiences.

II. COURSE CONTENT

This course should be structured around practical applications of physical science concepts used by local industries, trades, agribusinesses, and health-related fields. Every attempt should be made to correlate these topics with applications found in the community through laboratory activities and demonstrations. This will enable students to gain an understanding of how the applied concepts associated with physical science are used locally. **A minimum of six topics listed below** should be selected and integrated into the curriculum during the school year.

A. Practical applications

1. Devise and conduct a controlled experiment with only one variable.
2. Compare the metric and English units used to measure the engine capacity and repair tools for automobiles and motorcycles.
3. Analyze the methods used to measure strengths of antifreeze used in automobile and truck radiators.
4. Determine the methods used to prepare soaps, detergents, cold creams, hand lotions, tooth pastes, athlete's foot powders, deodorant liquids, and lipsticks.
5. Trace the energy changes from one form to another in an automobile, television, computer, nuclear power plant, coal power plant, or school heating system.
6. Identify elements with diffraction grating.
7. Analyze the process involved in the manufacture of lime, mortar, plaster, cement, and concrete.
8. Determine the chemical reactions used to produce fertilizers and the importance of these compounds in the soil.
9. Investigate the problems associated with acid rain.
10. Contrast the function of antifreeze and coolant in radiators.
11. Compare the methods used to dispose of nuclear wastes.
12. Investigate the methods used to determine horsepower.
13. Locate the center of gravity on 18-wheelers, sports cars, passenger cars, jeeps, high riders, compacts, and motorcycles.
14. Investigate the use of laser technology and holography.
15. Determine the uses of polarization of light.

16. Investigate the use of electrostatic precipitators to clean air.
17. Predict the use of battery-powered cars as a means of transportation.
18. Analyze the function of electronic devices such as vacuum tubes, transistors, and integrated curcuits in instruments and appliances.
19. Determine the effect of inertia and gravity on orbiting satellites.

B. Principles

1. The nature of science

   a. Experimental nature of science
   b. Laboratory safety procedures

2. Measurements

   a. Metric measurement systems and techniques
   b. Interpretation of graphs
   c. Exponential notation and significant digits (optional)

3. Properties of matter

   a Density of solids, liquids, and gases
   b. Specific gravity and buoyance
   c. State of matter dependent on temperature
   d. Solutions
   e. Physical and chemical properties
   f. Physical and chemical changes

4. Energy

   a. Potential and kinetic energy
   b. Conversion from one form to another

5. Atomic structure

   a. Elements, compounds, and mixtures
   b. Nomenclature of compounds
   c. Periodic table

6. Chemical reactions

   a. Composition, decomposition, single and double replacement reactions
   b. Balance simple equations

7. Acids, bases, and salts

   a. Neutralization reactions and salt formation
   b. pH scale and indicators
   c. Properties and uses of industrial acids
   d. Strengths of acids and bases (optional)

8. Temperature and heat

   a. Temperature scales
   b. Expansion and contraction of solids, liquids, and gases
   c. Heat transfer in refrigeration and heating

9. Radioactivity

   a. Types and properties of radioactive materials
   b. Detection, shielding, and waste disposal
   c. Uses of radioactivity in medicine, energy, and dating

10. Mechanics

   a. Velocity and accelerated motion
   b. Newton's three laws of motion
   c. Work, power, and horsepower
   d. Friction
   e. Simple machines
   f. Engines

11. Wave motion, sound and light

   a. Wave types and properties
   b. Reflection, refraction of plane, concave, and convex mirrors and lenses
   c. Refraction of concave and convex lenses
   d. Doppler effect

12. Static charges and current electricity

   a. Types of charges
   b. Direct and alternating current
   c. Lights and wiring in series and parallel
   d. Ways of producing and measuring current electricity

13. Magnetism and electromagnetism

   a. Magnetic poles and fields
   b. Operation of relays, motors, buzzers, telephones, and transformers

14. Electronics

    a. Cathode-ray tubes and television
    b. Digital computers
    c. Vacuum tube and transistors (optional)

15. Space science

    a. Space flights
    b. Launching and orbits